

FEASIBILITY TESTING OF
IN SITU VITRIFICATION OF
NEW BEDFORD HARBOR SEDIMENTS

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SUMMARY

A process feasibility study using in situ vitrification (ISV) was successfully performed on PCB-contaminated sediment for Ebasco Services Corporation. In situ vitrification is a thermal treatment process that converts contaminated soils and wastes into a durable glass and crystalline form. During processing, heavy metals, or other inorganic constituents, are retained and immobilized in the glass structure; organic constituents are typically destroyed or removed for capture by an off-gas treatment system.

The destruction and removal efficiency (DRE) for the ISV system, without the benefit of off-gas treatment, is greater than 99.9985%. This value represents the amount of PCBs not released to the off-gas system. This DRE does not include the removal efficiency of the off-gas system itself. Based on a single-stage activated carbon filter having a 99.9% organic removal efficiency, the ISV system soil-to-stack DRE with a single-stage carbon filter is estimated to be greater than 99.99999% (seven nines). This is greater than the 99.9999% efficiency required by 40CRF761.70 for PCB incinerators.

An overall system mass balance for PCBs was performed. The mass balance determined that greater than 99.94% of the total PCBs were destroyed by the ISV system. The % PCBs destroyed was calculated by subtracting the amount released to the off-gas system, plateout within the system, amount in glass matrix (none detected; used detection limit for calculation), and the suspected amount of migration to the surrounding soil. This mass balance is based on worst-case interpretation and is not confirmed by actual measured presence of PCBs.

Based on the initial test results, the potential for ISV treatment of New Bedford Harbor sediments is indicated. Adequate technical bases are available to demonstrate the ISV process capabilities and applications to PCB-contaminated sediments.

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INTRODUCTION

As management of hazardous materials gains increased attention in the United States and throughout the world, new, more effective technologies are being sought to immobilize and/or destroy the materials either in situ for previously disposed wastes, or at the waste generation site. New and proposed environmental regulations are making landfill disposal very costly and will eventually limit land disposal. Furthermore, the extended liability associated with future environmental impairment provides a significant corporate incentive to dispose and delist hazardous chemical wastes within the plant or waste site boundary.

Battelle, Pacific Northwest Laboratories (BNW), a division of Battelle Memorial Institute (BMI), has developed a remedial action process for contaminated soils that is significant in its application to these concerns. The process, called in situ vitrification (ISV), was initially developed to demonstrate a potential technology for disposal of soil contaminated with transuranic waste, although recent tests have shown that many hazardous chemical wastes are also destroyed or immobilized as a result of the treatment. In situ vitrification was originally developed for the U.S. Department of Energy (DOE) by the Pacific Northwest Laboratory^(a). BMI has established a commercial company named Geosafe for application of the ISV process to chemically hazardous wastes. This report presents evidence that ISV also has applicability to New Bedford Harbor sediment, which is contaminated with polychlorinated biphenyls (PCBs).

In situ vitrification is a thermal treatment process that converts contaminated soils into a chemically inert and stable glass and crystalline product. The ISV process could be applied to many contaminated soil sites. The processing would be performed in place or on excavated soil/sludge; high

(a) The Pacific Northwest Laboratory is operated for the U.S. Department of Energy by Battelle Memorial Institute. Battelle, Pacific Northwest Laboratories is a division of Battelle Memorial Institute.

temperature would destroy or remove organic contaminants, and the glass would encapsulate any inorganic contaminants. All these functions would be performed in one processing step.

This report presents the results of a bench-scale ISV treatability test conducted for the Ebasco Services Corporation. The primary objective of this study was to determine the applicability of the ISV process to PCB-contaminated sediments from New Bedford Harbor. Testing results determined the amount of destruction of PCBs and that no residual PCBs were detected in the vitrified product. Fractional release of PCBs to the off-gas treatment system and Toxicity Characteristic Leaching Procedure (TCLP) test performance of the vitrified material were also determined.

Based on the results of this report on PCB-contaminated sludges and ISV applications to specific sites, ISV offers technical and economic improvements to state-of-the-art remedial action technology. With an understanding of the process design and functions, the waste manager can make sound judgments about the applicability of ISV to site-specific disposal problems.

CONCLUSIONS

Feasibility testing of the ISV process was successfully performed on New Bedford Harbor sediment contaminated with PCBs. Analyses of the test data provides the following conclusions regarding the performance of the ISV process:

- Plate-out of PCBs existed in the off-gas collection plenum at below analytical detection limits.
- Minimal migration of PCBs to the soil surrounding the vitrification zone occurred. The largest detectable amount of PCBs is less than 1 ppm, which is below a common level of concern; this detectable amount is based on the suspected presence of PCBs, limited by analytical detection techniques. Areas outside of the 100°C isotherm also need to be tested for confirmation of limits of migration.
- No detectable amount of PCBs is present in the vitrified product.
- TCLP testing resulted in leach extract that contained metal concentrations below the regulatory limits.
- Very small amounts ($\leq 2\%$) of Cd and Pb were volatilized by the process.
- The low levels of Cl released do not raise concern for off-gas system corrosion. Further testing is recommended to determine amount of Cl remaining in glass and amount of Cl_2 in off-gas.
- The soil-to-off-gas destruction/removal efficiency (DRE) for the ISV system is greater than 99.9985%. This value represents the amount of PCBs not released to the off-gas system and is based on analytical detection limits. Based on a single-stage activated carbon filter having a 99.9% organic removal efficiency, the ISV system soil-to-stack DRE is estimated to be greater than 99.99999% (seven nines).
- The overall system PCB mass balance showed that greater than 99.94% of the total PCBs were destroyed by the ISV system. This value accounts for the limited amount of outward migration to the surrounding soil (based on suspected presence--limited by analytical detection techniques), as well as residuals in the vitrified product (based on detection limits) and the amount collected by the off-gas system.

Initial testing indicates the potential for ISV treatment of New Bedford Harbor sediments. Based on the results of the feasibility test, adequate technical bases are available to demonstrate the ISV process capabilities and applications to PCB-contaminated sediments.

PROCESS DESCRIPTION AND STATUS OF DEVELOPMENT

In situ vitrification has been developed as a remedial action process for soils contaminated with hazardous chemical wastes and/or radionuclides. Figure 1 illustrates the operation of the ISV process. Four molybdenum (Mo)/graphite electrodes in a square array are inserted into the ground to the desired treatment depth. Because soil is not electrically conductive when its moisture has been driven off, a conductive mixture of flaked graphite and glass frit is placed among the electrodes to serve as a starter path. An electrical potential is applied to the electrodes to establish an electrical current in the starter path. The flow of current heats the starter path and surrounding soil to well above the initial soil-melting temperatures of 1100°C to 1400°C. The graphite starter path is eventually consumed by oxidation and the current is transferred to the molten soil, which is processed at temperatures between 1450°C and 1600°C. As the molten or vitrified zone grows, it incorporates or encapsulates any radionuclides and nonvolatile hazardous elements, such as heavy metals, into the glass structure. The high temperature of the process destroys organic components by pyrolysis. The pyrolyzed byproducts migrate to the surface of the vitrified zone, where they combust in the presence of air. A hood placed over the area being vitrified directs the gaseous effluents to an off-gas treatment system.

The process can also accommodate a staging operation alternative. In this processing alternative, outlying materials are placed on the surface of an area to be vitrified to increase the effective vitrification depth. Since ISV is a batch operation, this alternative will increase the amount of material vitrified in each batch setting, thereby improving the efficiency of the operation.

Battelle, Pacific Northwest Laboratories began developing ISV technology in 1980. Since that time, numerous experimental tests under a variety of conditions and with a variety of waste types have been conducted (Buel et al. 1987, Timmerman and Oma 1984, Timmerman et al. 1983, Buel and Carter 1986, Timmerman 1986). Table 1 describes the different scales of testing

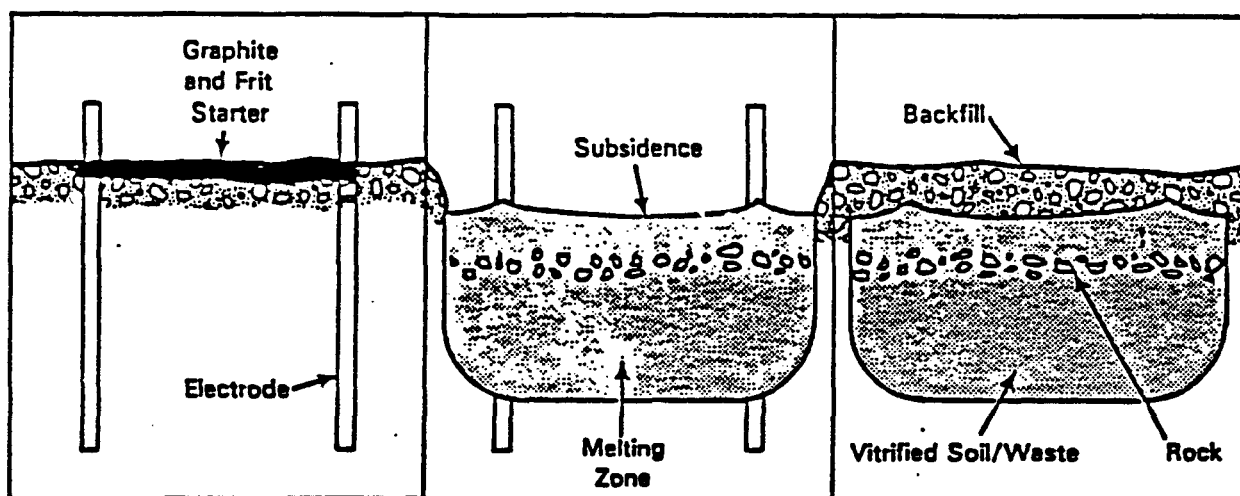


FIGURE 1. The Process of In Situ Vitrification

TABLE 1. Testing Units for Developing In Situ Vitrification Technology

<u>Equipment Size</u>	<u>Electrode Separation, m</u>	<u>Block Size</u>	<u>Tests Completed As of 10/31/88</u>
Bench scale	0.11	1 to 10 kg	12
Engineering scale	0.23 to 0.36	0.05 to 1.0 t	26
Pilot scale	0.9 to 1.5	10 to 50 t	16
Large scale	3.5 to 5.5	400 to 800 t	5

units that BNW uses in developing and adapting ISV technology. The successful results of 59 bench-, engineering-, pilot-, and large-scale tests have proven the general feasibility and widespread applications of the process. Also, economic studies have indicated that tremendous economies-of-scale are attainable with the ISV process (Oma et al. 1983). The technology has been refined to the point that it is now ready for technology transfer and commercialization for specific hazardous waste types.

The ISV process has been broadly patented within the United States, Canada, Japan, Great Britain, and France. BMI recently transferred a partially exclusive license to those patents to Geosafe Corporation for non-federal U.S. government, nonradioactive waste applications. Geosafe, located

in Kirkland, Washington, specifically provides commercial hazardous waste remediation services to public and private customers using its proprietary ISV process.

The decision to proceed with the design, fabrication, and testing of the existing large-scale unit was made on the basis of the extensive database developed as a result of engineering- and pilot-scale tests. The pilot-scale unit demonstrated the process using radioactively spiked soils and provided support for the decision to design and fabricate the large-scale system. Subsequent tests have been conducted with the bench-, engineering-, and pilot-scale units to determine processing behavior under various waste conditions and to develop improved operating techniques.

The large-scale process equipment for transuranic (radioactive) contaminated soils has been fabricated and installed (Figure 2), and the large-scale operational acceptance tests and a large-scale verification test have been completed. The objective of these tests was to verify conformance of the process characteristics to the established functional design criteria relevant to the large-scale radioactive test. The large-scale testing culminated in successful operation of the large-scale radioactive test on an actual radioactively contaminated soil site at Hanford in Washington state.

The extensive technical data for the ISV process establish the performance of the system and waste form, economics and safety, and waste site applications for radioactive and hazardous chemical wastes. These aspects of the process are summarized as follows:

- The minimum estimated depth limit of the large-scale ISV system is 10 m in Hanford soils, independent of moisture content. Computer model predictions show that melt depths in excess of 20 m should be attainable. Depths in excess of 5 m have been demonstrated.
- Radionuclides and heavy metals are sufficiently retained within the melt, and nitrates and organics are destroyed during processing.
- Generally, environmental regulations do not allow the direct evolution of the small percentage of heavy metals and organics that escape from the vitreous mass during processing. Therefore, an off-gas treatment system is included in the process to remove the contaminants from the gaseous effluents.

In Situ Vitrification

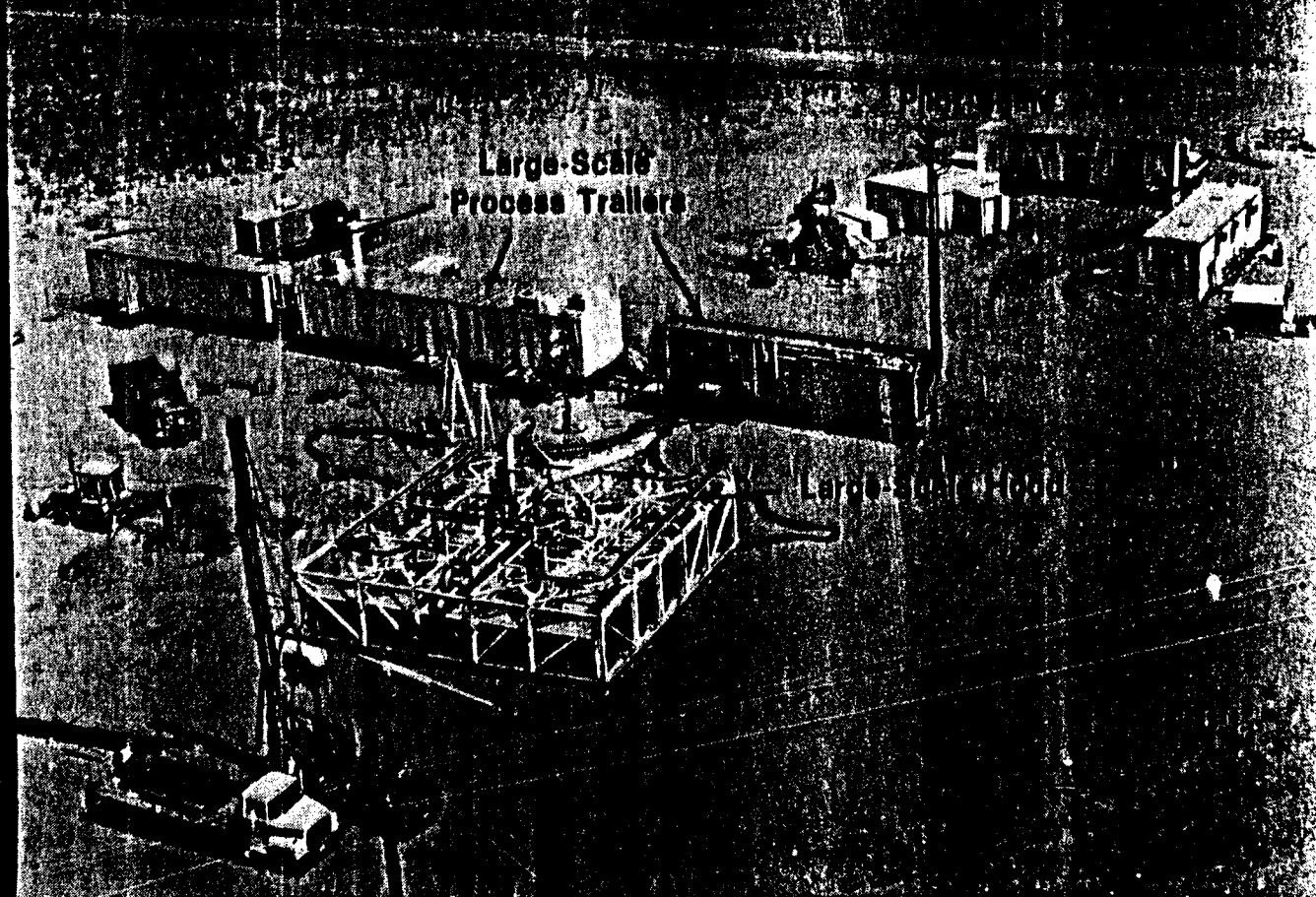


FIGURE 2. In Situ Vitrification Test Site

- A depth transmitter system has been developed for reliable monitoring of the vitrification zone depth during processing.
- A reference electrode design has been established for future ISV applications. This design employs a Mo/graphite combination to promote subsidence of the surface of the melt below the original soil grade. Oxidation of Mo during processing is prevented by the graphite collar, plus a fused coating of MoSi_2 on the Mo electrode core.
- Metal inclusions do not significantly affect the ISV process unless a full electrical short circuit is approached.
- Cement inclusions are completely dissolved within the glass waste form.
- In situ vitrification is capable of processing various soil types throughout the United States. Soils from nine different U.S. locations were found to be similar in the properties that could affect the ISV process. Similar ISV processing capacity is anticipated for other worldwide soil types.
- The ISV waste form is expected to surpass established and proposed toxicity tests. Leachability of vitrified soil has been measured to establish and confirm these conditions.
- Soil moisture generally increases the time and power required to vitrify a waste site; however, the effect of moisture on the maximum attainable depths of ISV is small. Industrial sludges with a total moisture content (amount of water in the soil) as high as 70 wt% have been vitrified by ISV.

LARGE- AND PILOT-SCALE PROCESS SYSTEMS

Development and deployment of the large-scale ISV system is the ultimate goal of the ISV program because the large-scale system is less costly to operate, and is more adaptable to numerous types of waste sites than the pilot-scale system. The cost of vitrifying a given waste volume with the large-scale system is one-seventh that for the pilot-scale system. The large-scale system is more adaptable because its high-capacity off-gas system, which can process off gas at a rate of 104 std m³/min, is better equipped to contain sudden gaseous releases from combustible and other gas-generating wastes. Nevertheless, the pilot-, engineering-, and bench-scale systems provide important data that are used to determine the performance of the large-scale system at a significantly reduced development cost. The existing large- and pilot-scale units owned by the U.S. Department of Energy and tested by Battelle Northwest under its contract to operate the Pacific Northwest Laboratory are described in this section. Commercial remediation services for nonfederal, nonradioactive waste sites are currently available from Geosafe Corporation. The Geosafe large-scale system is very similar to the DOE system.

LARGE-SCALE SYSTEM

The large-scale system described in this section is designed to vitrify contaminated soils with an electrode separation of up to 5.5 m on a side. The specific process description is for a system that could be applied to highly contaminated portions of TRU-contaminated soil sites, caissons, and solid waste burial sites. The ISV large-scale process equipment is shown in Figure 3. Controlled electrical power is distributed to the electrodes, and special equipment contains and treats the gaseous effluents. The process equipment required to perform these functions can be described most easily by dividing the equipment into six major components:

- electrical power supply
- off-gas hood
- off-gas treatment system

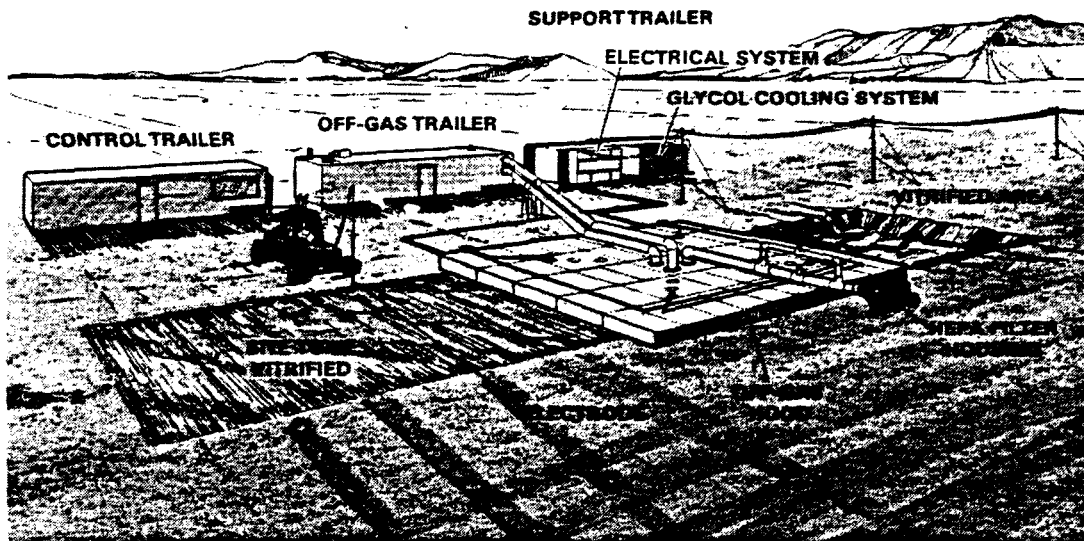


FIGURE 3. Large-Scale Process Equipment for In Situ Vitrification

- glycol cooling system
- process control station
- off-gas support equipment.

Except for the off-gas hood, all of the components are contained in three transportable trailers, as shown in Figure 4. They consist of an off-gas trailer, a process control trailer, and a support trailer. All three trailers are mounted on wheels to accommodate a move to any site over a compacted ground surface. The off-gas hood and off-gas line, which are installed on the site to collect gaseous effluents, are dismantled and placed on a flat-bed trailer for transport. The effluents exhausted from the hood are cooled and treated in the off-gas treatment system. The entire process is monitored and controlled from the process control station. Buelt and Carter (1986b) provide a detailed description and design basis for the process, but a brief summary is also provided here.

Power System

The power system for the ISV process uses a Scott-Tee® transformer connection to convert three-phase electrical power to two single-phase loads (Lazar 1977). Each single-phase load is connected to two electrodes, arranged in a square pattern, as shown in Figure 5. The Scott-Tee

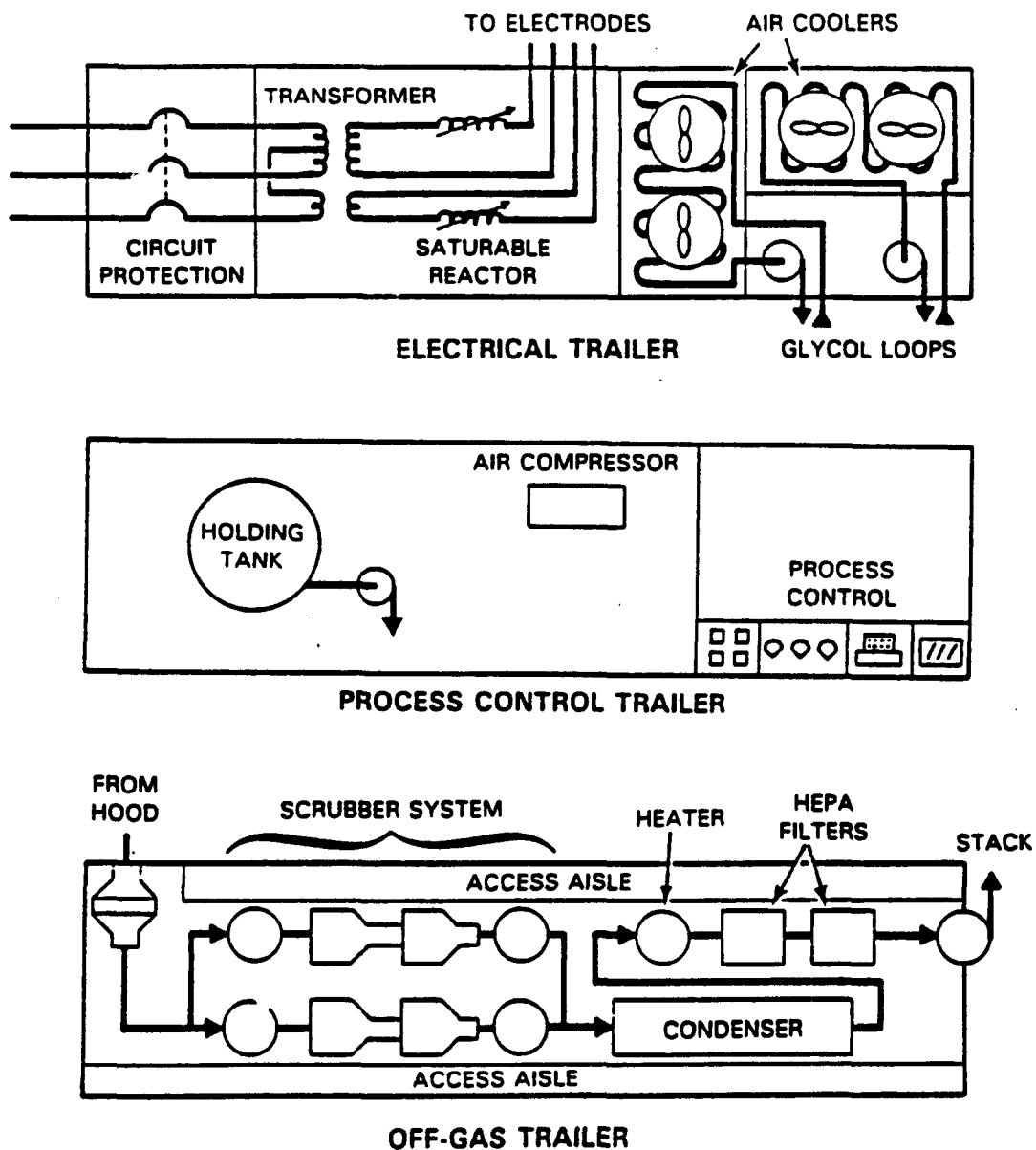


FIGURE 4. Process Trailers for Large-Scale In Situ Vitrification

transformer was selected on the basis of its even distribution of current within the molten soil, which produces a vitrified product almost square in shape to minimize the overlap between adjacent settings. The connection has been employed during pilot- and engineering- scale tests and is commonly used in the glass industry.

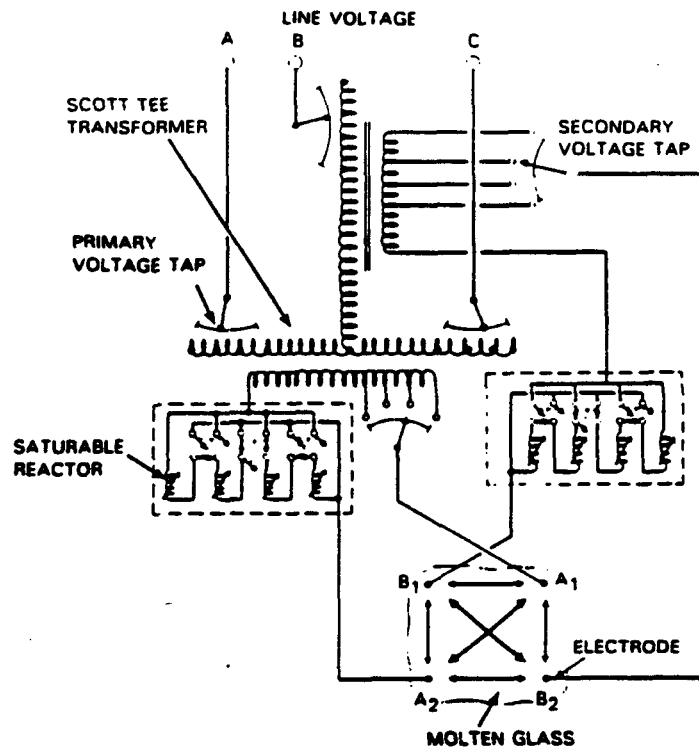


FIGURE 5. Scott-Tee Transformer Design for the Large-Scale System

The vitrification zone continually grows as the ISV process is supplied with power. This creates a constantly changing voltage/current relationship, which requires multiple voltage taps on the Scott-Tee transformer. The multiple taps allow for more efficient use of the power system by maintaining the power factor (the phase relationship between current and voltage) near maximum, which is 3750 kW for the large-scale system. Figure 6 shows the increase in the achievable average power input when using 16-voltage taps rather than 4-voltage taps. Average power is 2900 kW when 4-voltage taps are used. With 16-voltage taps the average power has been increased to 3500 kW, which is much more efficient use of the maximum capabilities of the system.

To control the current and/or voltage being introduced into the electrodes, saturable reactors with their respective control windings are used for the large-scale system. The control scheme is to use two saturable reactors on the secondary side of the Scott-Tee transformer. This has the advantage of independently controlling the power to each of the single-phase

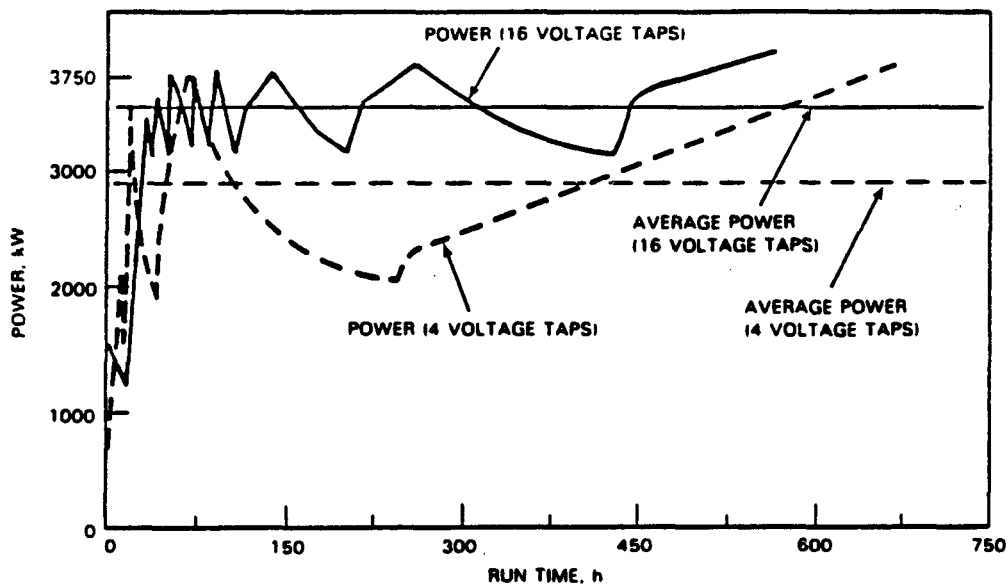


FIGURE 6. Effect of Increased Number of Voltage Taps on Average Power Output

loads. However, the saturable reactors had to be designed to accommodate the full voltage and current ranges caused by the variable resistance of the melt in this batch operation process. This requires multiple reactors for each phase connected in series and/or parallel to be compatible with the range of voltage and current ratings.

The power supply system was specified to meet functional criteria determined by a mathematical model. From the mathematical simulations, a 3750-kW power supply was selected for the large-scale system. The modeling predictions also stipulate that to meet the functional criteria, a load voltage of between 4160 to 400 V must be supplied with a corresponding current capacity on each of the two secondary phases of between 450 and 4000 A, respectively.

Off-Gas Containment and Electrode Support Hood

A stainless steel off-gas hood is placed over the vitrification zone to contain any gaseous and radioactive effluents from the process and to direct them to the portable off-gas treatment system. The hood (shown in Figure 7) is kept under a slightly negative pressure (0.25- to 2.5-cm water).

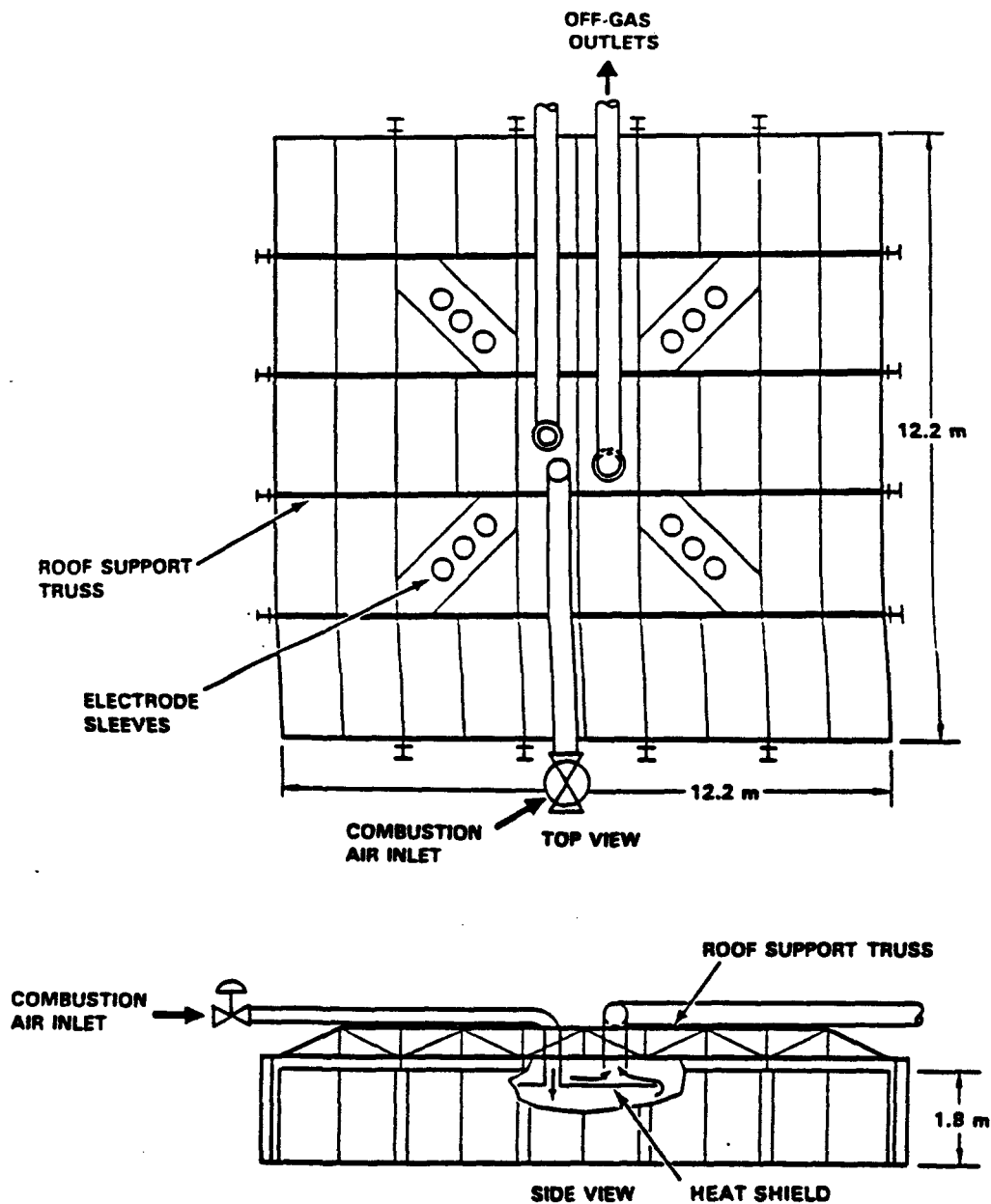


FIGURE 7. Off-Gas Containment Hood for the Large-Scale System

The hood is constructed of 2.4- x 1.2-m panels that can be dismantled and stored in type A^(a) transportation containers. Because of the high heat load from burning combustible wastes at the vitrification surface, the

(a) Hanford radioactive shipment classification.

off-gas hood is constructed of materials that are capable of withstanding 900°C. A nonwelded (bolted) hood design was favored for the large-scale system because thermal expansion from ambient temperature to 900°C creates >2.5-cm expansion in any direction. The panels are assembled in a manner to relieve stresses that might result from thermal expansion. The existing hood is designed for a skin temperature of 550°C; higher combustible loadings in the soil, for which the off-gas treatment system is designed, would require a high-temperature hood design.

The hood is sealed to the surface of the soil surrounding the zone to be vitrified by a flexible skirt of tightly woven, high-temperature resistant fiber covered with a few centimeters of dirt. The skirt maintains a seal during processing, which normally tends to dry out the dirt around the hood, thereby increasing air inleakage.

The four Mo electrodes protrude through the hood at variable separations of 3.5 m to 5.5 m on a side. They are surrounded by electrically insulated sleeves that allow for the adjustment of the electrode position. The electrodes are supported by insulators above the sleeve. The insulators are designed to withstand any movement of the molten mass against the electrodes caused by convective currents and the gravitational or buoyant forces exerted on the electrodes.

Off-Gas Treatment System

The off-gas treatment system (see Figure 8) cools, scrubs, and filters the gaseous effluents exhausted from the hood. Its primary components include a gas cooler, two wet scrubber systems (tandem nozzle scrubbers and quenchers), two heat exchangers, two process scrub tanks, two scrub solution pumps, a condenser, three mist eliminators (vane separators), a heater, a high-efficiency particulate air (HEPA) filter assembly, and a blower system. The HEPA filter assembly can be replaced with a dual-stage activated carbon adsorption assembly, if appropriate (e.g., PCB/organic waste remediation).

Due to the additional heat load from high concentrations of buried solid and liquid organic combustibles, off gases entering the off-gas trailer can be expected to reach a maximum temperature of 750°C. To keep the size of the

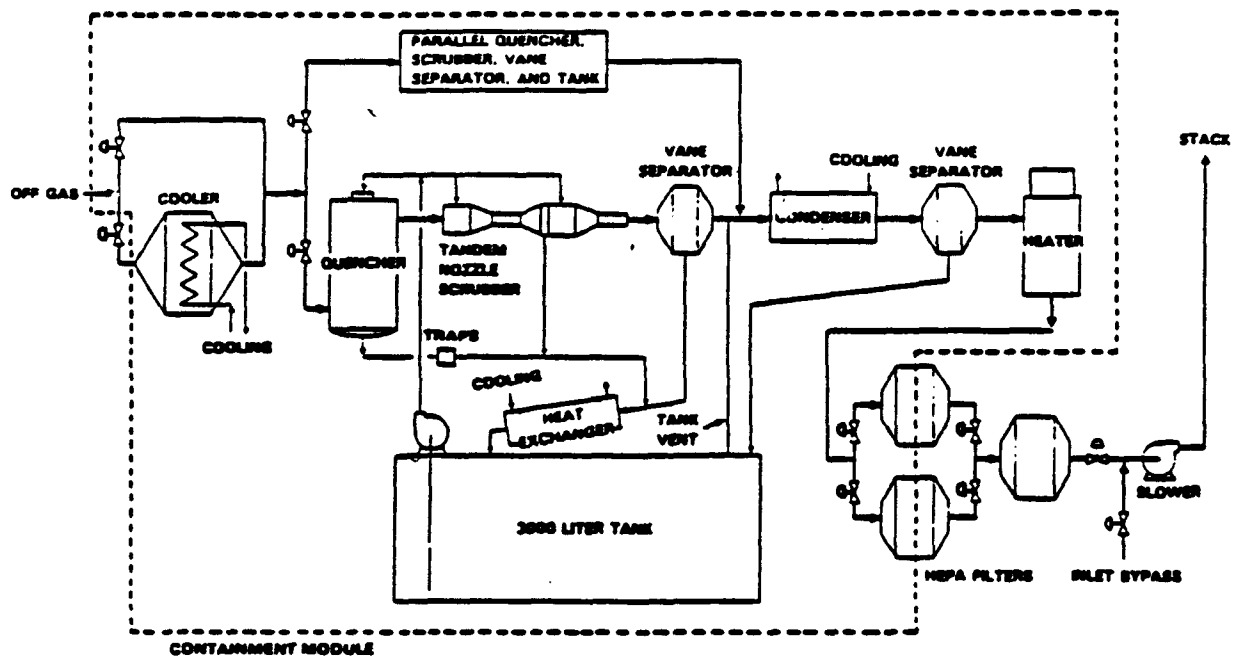


FIGURE 8. Off-Gas System for Large-Scale In Situ Vittrification

heat exchange equipment manageable for a transportable facility, a gas cooler is provided to remove a major portion of the heat load from the off gases before quenching. The gas cooler is a finned air-to-glycol heat exchanger. It is capable of transferring 1100 kW from the off gas to a glycol loop, cooling the gases to 300°C. The gas cooler can be bypassed by operating three 40-cm pneumatic-actuated butterfly valves.

From the gas cooler, the off gas is split and directed into two wet scrubber systems that operate in parallel. Two scrubber systems provide an operating flow range of between 30 and 104 std m³/min. At flows less than 60 std m³/min only one system operates. The dual scrubber system also provides redundancy in the event of single-component failure. Each system is composed of a quench tower, a tandem nozzle scrubber, and a vane separator. The quencher reduces the gas temperature from 300°C to 66°C, and provides some scrubbing action to remove a portion of the particles and semivolatile radionuclides. The primary functions of the tandem nozzle scrubber are to remove any remaining particles that are ≥0.5 μm dia, condense the remaining

semivolatile components, and provide additional cooling of the off gas. The vane separator that follows each tandem nozzle scrubber is designed to remove all droplets $\geq 12 \mu\text{m}$.

The scrub solution that is injected into the quenchers and tandem nozzle scrubbers is cooled through two single-stage heat exchangers before being returned to the process scrub tanks. Each heat exchanger can remove 120 kW from the scrub solution and transfer 120 kW of heat to the glycol solution.

Two independent scrub pumps recirculate the scrub solution from the process tanks to the wet scrubbers. Each pump can deliver 510 L/min with a maximum deliverable pressure of 680 kPa. In addition, the scrub pumps can flush out the gas cooler and off-gas piping that are not wetted by the wet scrubbers.

Following the scrubber systems, the off gas is recombined and cooled. A condenser and mist eliminator provide additional decontamination of the off gas by condensing it and removing water droplets. The condenser transfers 320 kW from the off gas into flowing glycol. The mist eliminator, a vane separator, removes droplets $\geq 12 \mu\text{m}$. Both the condenser and mist eliminator are rated at 104 std m^3/min . Final decontamination of off-gas particulates is achieved in the two-stage HEPA filter assemblies. The first stage is composed of two parallel housings, each capable of holding four 61-cm-high x 30-cm-deep filters. With this arrangement, one filter set can be changed out without interfering with the continuous operation of the off-gas system.

The gaseous effluents are drawn through the off-gas system components by an induced draft system. The driving force is provided by a 149-kW (200-hp) blower that is capable of achieving 104 std m^3/min at 90°C and -229 cm of water. A back-up blower rated at one-quarter the capacity is available if the primary blower fails. The back-up blower is not intended to provide excess combustion air, but rather to maintain a negative pressure on the off-gas hood to prevent direct release of effluents until the process can be safely shut down. The back-up blower is automatically activated by the process control system when the main blower header vacuum is reduced below a

preset limit. After passing through the blower system, the off gases are exhausted to the stack, which is monitored continuously for radionuclides, NO_x , and SO_2 . The stack is removable and extends high enough to prevent interference with the off-gas and control trailer's heating, ventilating, and air conditioning (HVAC) systems.

Glycol Cooling System

Glycol cooling solution is pumped between the support trailer and off-gas trailer to remove the heat from the gaseous effluents. The glycol is recirculated between trailers through flexible jumpers by two pumps in two independent loops. The glycol recirculating through the heat exchangers and condensers is kept separate from the glycol loop for the off-gas coolers. However, both loops are assembled in one glycol cooling assembly, which is located on the support trailer. The assembly consists of two fan-cooled radiator systems, each dedicated to its respective glycol loop. The entire assembly removes 1600 kW at an ambient temperature of 38°C.

Process Control Station

The process control station consists of a distributed microprocessor monitoring and control system and a control console for the power supply. The process control station monitors and controls important process parameters and automatically activates back-up equipment or reroutes off-gas flow if certain equipment fails.

The distributed microprocessor control system consists of two process control units and two operator interface units. The process control units are connected to critical and informational sensors located throughout the process. These include sensor readings from pressure elements, thermocouples, gas monitors, and flowmeters. In addition to monitoring key parameters, the control system performs the following functions:

- control of the pressure drop across the scrubber systems by a pneumatic flow control valve at the blower inlet
- control of the blower inlet vacuum with a separate pneumatic valve that governs the magnitude of recycle through the main blower
- control of off-gas differential temperature across the heater

- control of negative pressure in the hood by controlling combustion air flow through a pneumatic valve
- automatic batch logic sequencing of specific operations in the event of equipment failure (22 preprogrammed sequences are included).

As examples of the latter function, if power fails, the control system automatically restarts the off-gas system in a preprogrammed sequence on emergency generator power. If the pressure drop across the HEPA filters exceeds predetermined levels, the system automatically activates the parallel HEPA filter assembly. If either hood vacuum or oxygen concentration is reduced below minimum operating criteria, the system engages the standby scrubber system. And if the primary blower fails, the system automatically shuts down power to the electrodes and starts the back-up blower.

Although the control system is connected to sensors and to an automatic shutdown circuit on the electrode power supply system, it does not directly control the power supply. A separate control console fulfills that function. The power supply controller provides the necessary saturation current to the saturable reactors that govern the power to the electrodes. This control module maximizes the efficiency of the electrode power system and provides a quick reduction in power in the event of off-standard conditions.

Off-Gas Support Equipment

Various support and back-up equipment are necessary to ensure the safe operation of the off-gas system. This equipment provides electrical, water, and air services to the off-gas equipment. The support equipment includes a 750-kVA transformer; a 750-kVA diesel generator; an air compressor; and a process water supply tank, pump, and agitator.

Other than the need for electrical power, the ISV process is entirely self-contained. No outside water, sewer, or air services are required. Supply and waste waters are transported to the process trailer by tank truck on an as-needed or scheduled basis. The process is equipped with its own air compressor for actuation of the pneumatic valves and its own water supply tank for scrub solution makeup.

Power to the off-gas process equipment is provided through the 750-kVA transformer and distributed by the motor control center (MCC) from a 13.8-kV supply. If power to the transformer is interrupted, a transfer switch in the MCC automatically activates a standby 750-kVA diesel generator that is equipped with its own battery-powered cranking system. This generator provides emergency power to all off-gas system components, including the pumps and fans of the glycol cooling assembly, scrub pumps, heater, blower system, air compressor, and monitoring and control instrumentation. The MCC, located in the control trailer, provides power to this equipment and to the power supply control console and the supply pump and agitator for process water. The 112-kVA transformer, which provides 240-V and 120-V power from the 480-V supply, is also in the control trailer. The 120-V power is also tied into the emergency back-up power generator for emergency lighting.

PILOT-SCALE SYSTEM

The pilot-scale system uses four electrodes with a 1.2-m separation and consists of a power control unit, an off-gas containment hood over the waste site, and an off-gas treatment system that is housed in a portable semi-trailer (see Figure 9). Prior to and after a radioactive test, this same system was used on six nonradioactive tests. A previous pilot-scale system (Oma et al. 1983) preceded the present pilot-scale design to provide scale-up feasibility; however, it was not mobile or designed for radioactive materials.

Power System Design

Like the large-scale unit, the pilot-scale power system uses a Scott-Tee connection to transform a three-phase input to a two-phase secondary load on diagonally opposed electrodes in a square pattern. The 500-kW power supply may be either voltage or current regulated. The alternating current primary is rated at 480 V, 600 A, 3 phase, and 60 Hz. The three-phase input feeds a Scott-Tee-connected transformer (see Figure 5) to provide a two-phase secondary. The transformer has four separate voltage tap settings--1000 V, 650 V, 430 V, and 250 V. Each voltage tap has a corresponding amperage rating of 250 A, 385 A, 580 A, and 1000 A and an off-gas treatment system. Like

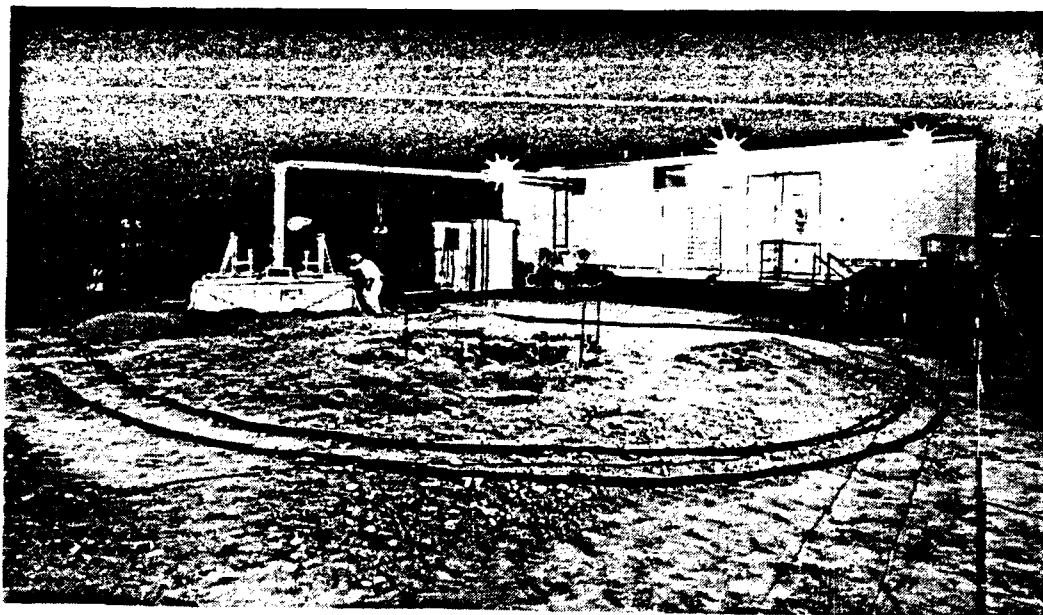


FIGURE 9. Hood and Process Trailer for Pilot-Scale In Situ Vitrification

the large-scale unit, the hood is equipped with a heat shield installed under the center top panel to protect the hood from heat that radiates from the partially molten surface during processing.

The hood makes use of the flexible skirt to provide a seal to the surface of the soil surrounding the zone to be vitrified. The skirt extends ~0.6 m away from the hood, allowing for a hood-to-ground seal when covered with a layer of soil.

Electrical bus bars, which are extensions of the Mo electrodes, protrude through the hood and are surrounded by electrically insulated sleeves that allow for the adjustment of the electrode positions. Figure 10 depicts one design of the insulated sleeves that was implemented during a pilot-scale radioactive test.

Off-Gas Treatment System

The off-gas system is shown schematically in Figure 11. The off gas passes through a venturi-ejector scrubber and separator, Hydro-Sonic® scrubber, separator, condenser, another separator, heater, two stages of HEPA

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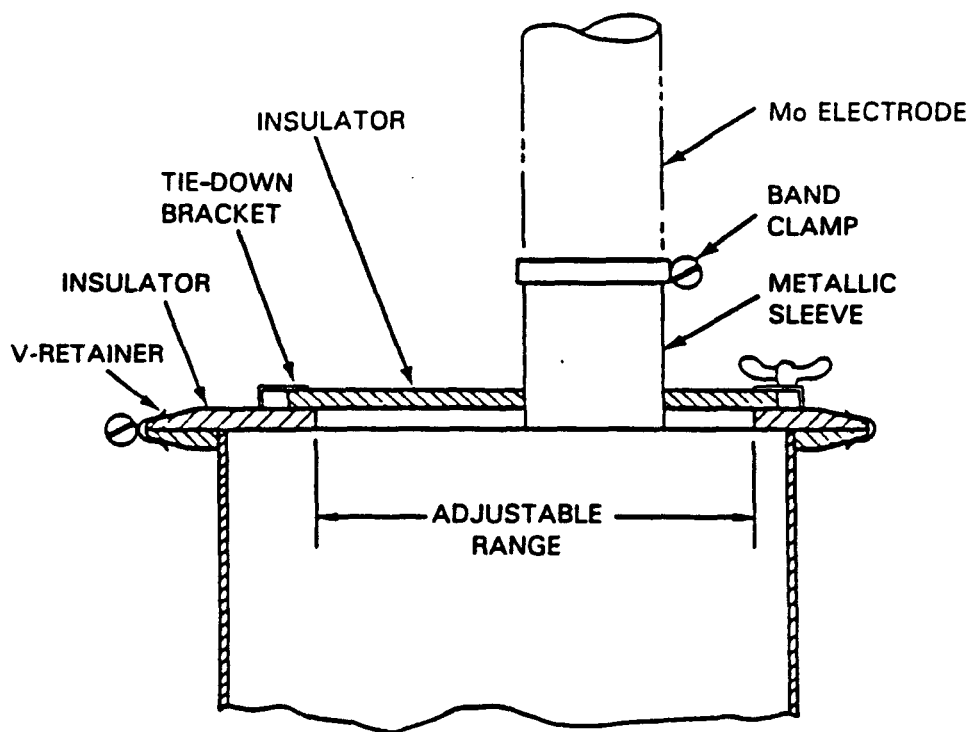


FIGURE 10. Design of Hood Feedthrough for Electrode Bus Bar

filtration, and a blower. Liquid to the two wet scrubbers is supplied by two independent scrub recirculation tanks, each equipped with a pump and heat exchanger. The entire off-gas system has been installed in a 13.7-m- (45-ft-) long semi-trailer to facilitate its transportation to a waste site. Equipment layout within the trailer is illustrated in Figure 12. Except for the second-stage HEPA filter and blower, all off-gas components are housed in a removable containment module that has gloved access for remote operations and is maintained under a slight vacuum (see Figure 13).

Heat is removed from the off gas by a closed loop cooling system that consists of an air/liquid heat exchanger, a coolant storage tank, and a pump. A 50% water/ethylene glycol mix is pumped from the storage tank through the shell side of the condenser and the two scrub solution heat exchangers, then through the air/liquid exchanger, where heat is removed from the coolant.

The venturi-ejector scrubber serves both as a quencher and a high-energy scrubber. The second scrubber is a two-stage Hydro-Sonic scrubber (tandem nozzle fan drive) as illustrated in Figure 14. The first section condenses

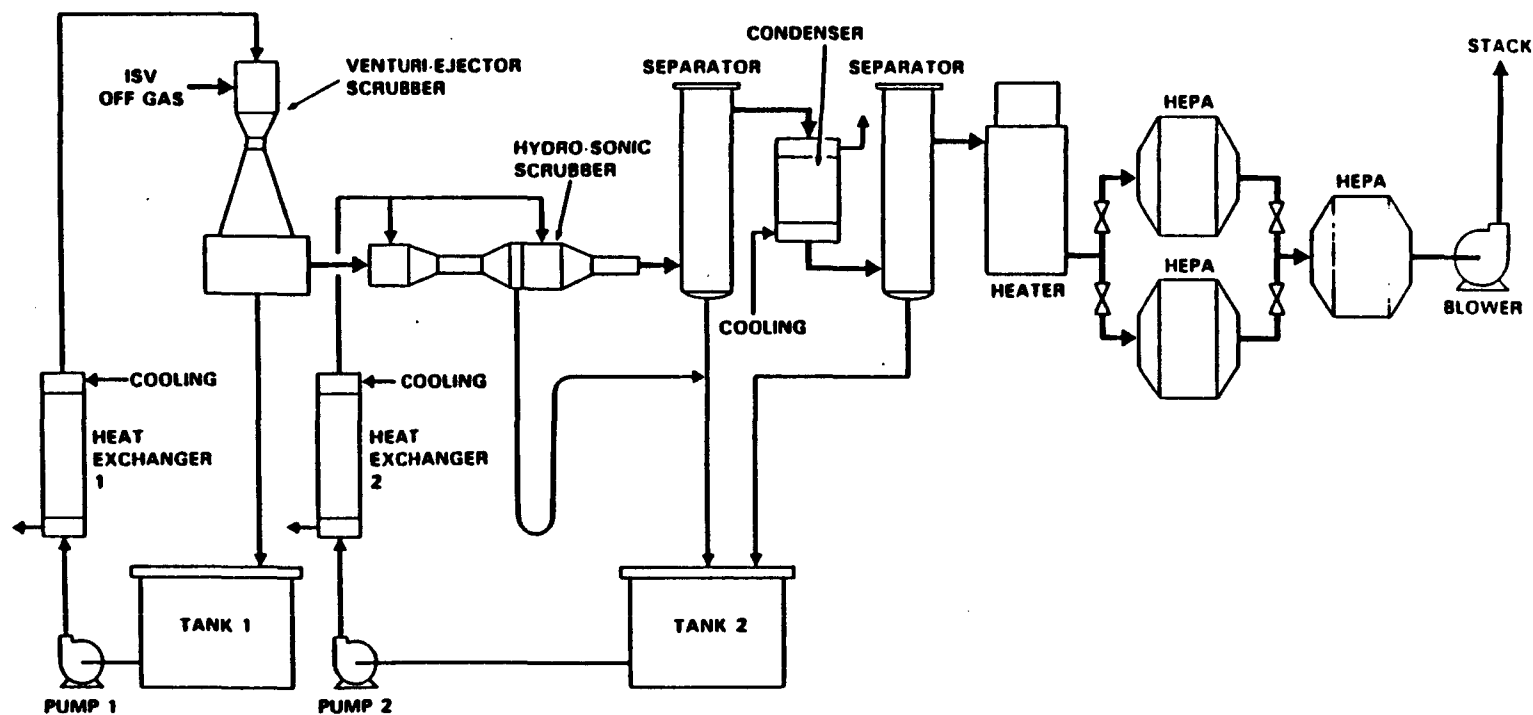


FIGURE 11. Off-Gas System Schematic for the Pilot-Scale ISV Process

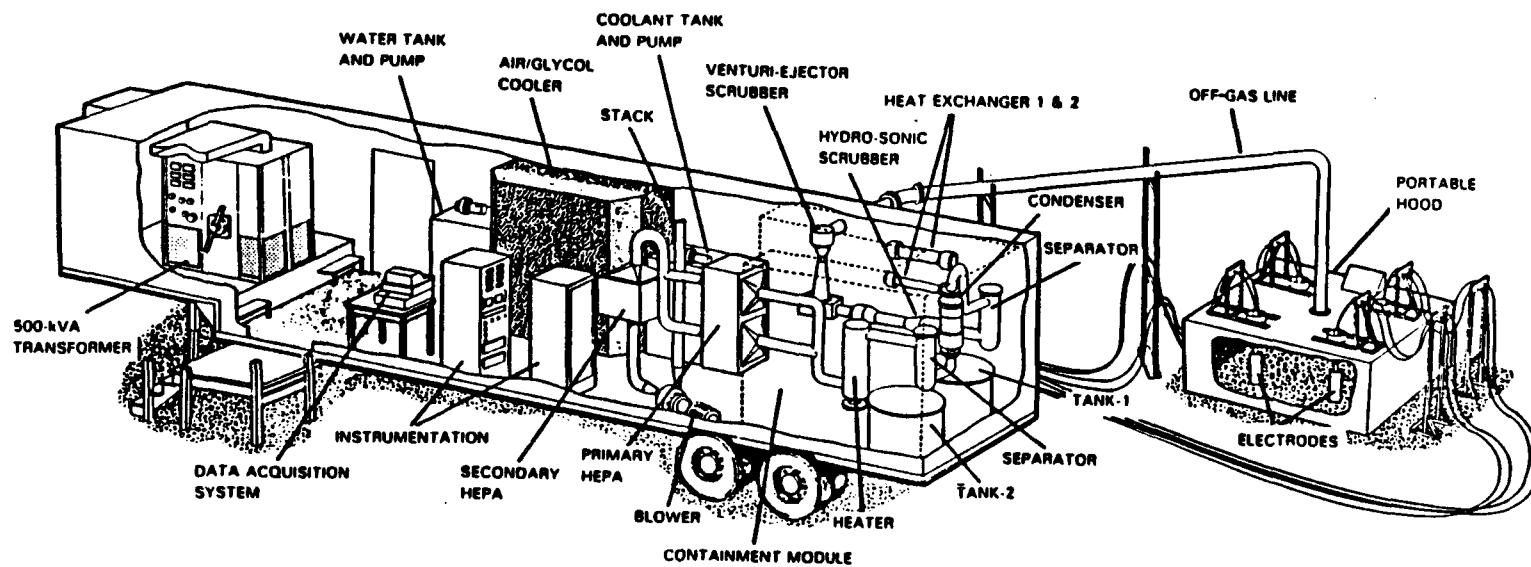


FIGURE 12. Cutaway View of Pilot-Scale ISV Process Trailer and Hood



FIGURE 13. Removable Containment Module for the Off-Gas Treatment System

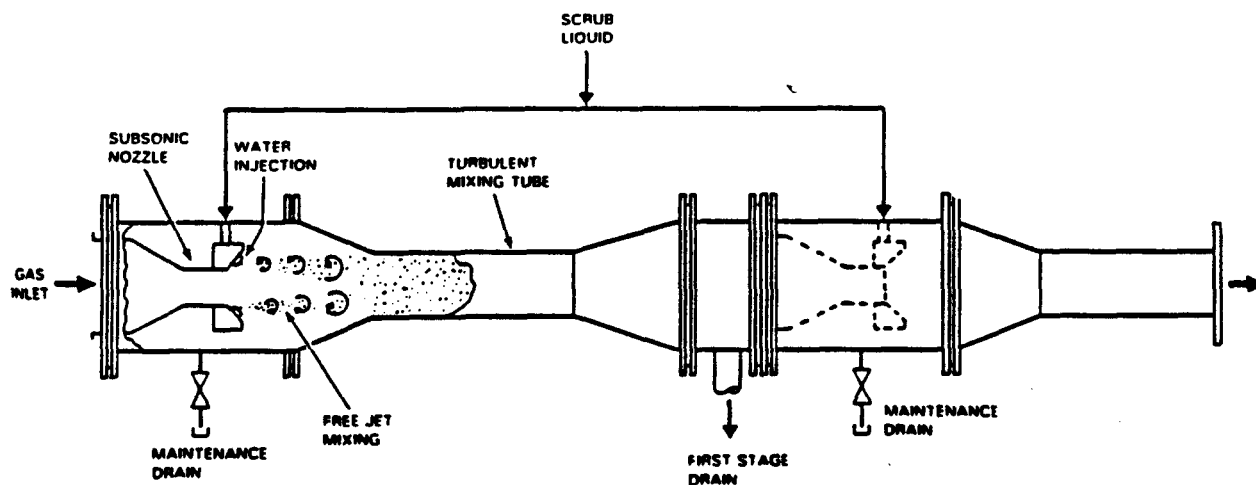


FIGURE 14. Tandem Nozzle Hydro-Sonic Scrubber (Hydro-Sonic Systems, Dallas, Texas)

vapors, removes larger particles, and initiates growth of the finer particles so that they are more easily captured in the second stage. Particulate is captured when the gas is mixed with fine water droplets produced by spraying water into the exhaust of the subsonic nozzle. Mixing and droplet growth continue down the length of the mixing tube. Large droplets containing the particulate are then removed by a vane separator and drained back into the scrub tank. The unit is designed to remove over 90% of all particulates greater than $0.5\text{-}\mu\text{m}$ dia when operated at a differential pressure of 127 cm of water. Removal efficiency increases with an increase in pressure differential.

Additional water is removed from the off-gas system by a condenser that has a heat exchange area of 8.9 m^2 and a final separator. The gases are then reheated to -25°C in a 30-kW heater to prevent condensate carryover to the filters.

The first stage of filtration consists of two 61- x 61- x 29-cm (24- x 24- x 11.5-in.) HEPA filters in parallel. During operation, one filter is used and the other remains as a back-up in case the generating filter becomes loaded. The primary filter can be changed out during operation. The second-stage HEPA filter acts as a back-up if a first-stage filter fails.

TEST DESCRIPTION

This section describes the bench- and engineering-scale ISV test equipment and off-gas system used for the New Bedford Harbor test, plus the specific test setup and operations. The bench-scale test was conducted using the engineering-scale processing container, off-gas system, and power supply to better simulate the power density, melt rate, and control of the larger-scale operational ISV systems.

SOIL AND SLUDGE CHARACTERIZATION

This section gives the compositions of the sludge and surrounding soil processed in the ISV test equipment. Table 2 lists the composition of the sludge. This analysis was provided by E. C. Jordan Co. Table 3 lists the composition of the Hanford soil, as oxides, used to surround the sludge in the test. The composition of the soil indicates that enough glass-forming materials (i.e., SiO_2 and Al_2O_3) and flux (i.e., Na_2O and K_2O) are present to form a durable glass product at the ISV process temperature range (1200°C - 2000°C).

TEST EQUIPMENT AND SETUP

The equipment used at BNW was a combination of a bench-scale sized test bed and the engineering-scale power supply and off-gas system. The actual vitrification took place in a halved 55-gallon drum, which was placed in the engineering-scale processing container. The sealed metal engineering-scale processing container shown in Figure 15 measures 1.8 m (6 ft) in diameter by 2.4 m (8 ft) tall. The processing container provided contaminated soil containment for the off-gas vacuum sealing. The single-phase engineering-scale power supply consisted of a 10-kW transformer with four voltage taps (400, 240, 160, and 80 volt), and silicon-controlled rectifier (SCR) control.

Two molybdenum electrodes, 1.27 cm (0.5 in.) in diameter with 3.81-cm (1.5-in.) diameter graphite collars, were inserted 17.8 cm (7 in.) into the test soil. The electrodes were spaced 12.7 cm (5 in.) apart. The modified 55-gallon drum was electrically isolated. The top of the soil surface was

TABLE 2. Composition of the New Bedford Harbor Sediment

<u>Semi-Volatile Organic Compounds</u>	<u>Analytical Method</u>	<u>CRDL (a)</u> <u>µg/kg</u>	<u>µg/kg</u>
1,3 - Dichlorobenzene		330	19,000
1,4 - Dichlorobenzene		330	55,000
4-Methylphenol		330	--
1,2,4, - Trichlorobenzene		330	54,000
Naphthalene		330	--
2-Methylnaphthalene		330	--
Acenaphthylene		330	--
Acenaphthene		330	--
Dibenzofuran		330	--
Fluorene		330	--
Phenanthrene		330	--
Anthracene		330	--
Di-n-Butylphthalate		330	--
Fluoranthene		330	--
Pyrene		330	--
Butylbenzylphthalate		330	--
Benzo (a) Anthracene		330	--
bis (2-Ethylhexyl) Phthalate		330	59,000
Chrysene		330	--
Benzo (b) Fluoranthene		330	8,000
Benzo (k) Fluoranthene		330	--
Benzo (a) Pyrene		330	--
Indeno (1,2,3-cd) Pyrene		330	--
Dibenz (a,h) Anthracene		330	--
Benzo (g,h,i) Perylene		330	--
<u>Pesticides/PCB</u>			
Aroclor-1242		80	5,000,000
Aroclor-1248		80	--
Aroclor-1254		160	5,500,000
<u>PCB Congeners</u>			
Monochlorobiphenyls			26,000
Dichlorobiphenyls			1,100,000
Trichlorobiphenyls			2,700,000
Tetrachlorobiphenyls			3,100,000
Pentachlorobiphenyls			1,600,000
Hexachlorobiphenyls			330,000
<u>Inorganic Compounds</u>			
	<u>Analytical Method</u>	<u>CRDL</u> <u>mg/kg</u>	<u>µg/kg</u>
Aluminum	P	40	22,100
Arsenic	F	2	15
Barium	P	40	207
Cadium	P	1	37
Calcium	P	1,000	5,440
Chromium	P	2	786
Copper	P	5	1,520
Iron	P	20	24,400
Lead	P/F	1	1,150
Magnesium	P	1,000	8,230
Manganese	P	3	194
Mercury	CV	0.04	2.4
Nickel	P	8	106
Potassium	P	1,000	--
Selenium	F	1	--
Sodium	P	1,000	14,200
Thallium	F	2	--
Vanadium	P	10	88
Zinc	P	4	3,250
%Solid			31.1
Dilution Factor			100

(a) Contract-required Detection Limit.

TABLE 3. Composition(a) of the Surrounding Soil

<u>Oxide</u>	<u>Wt%</u>
Al ₂ O ₃	13.0
B ₂ O ₃	0.053
BaO	0.068
CaO	6.33
Fe ₂ O ₃	10.0
K ₂ O	1.7
MgO	2.96
MnO ₂	0.193
Na ₂ O	2.80
NiO	0.077
P ₂ O ₅	0.429
SiO ₂	55.5
SrO	0.044
TiO ₂	1.92
ZrO ₂	0.041
TOTAL	95.1
Moisture (wt%)	0

(a) Soil from the Hanford site was used to surround the sediment in this test.

covered with 5.1 cm (2 in.) of blanket insulation to minimize surface heat loss and promote melt surface subsidence during processing. A gap in the insulation around each electrode provided a gas vent.

Type K thermocouples were incrementally positioned along the centerline and the side of the test container to monitor the progress of the melt and the surrounding soil temperature profiles (Figure 16). Not shown is an additional high-temperature type C thermocouple that was placed at the 11.4-cm (4.5-in.) centerline depth. The high-temperature thermocouple was used to determine the operating melt temperature during ISV.

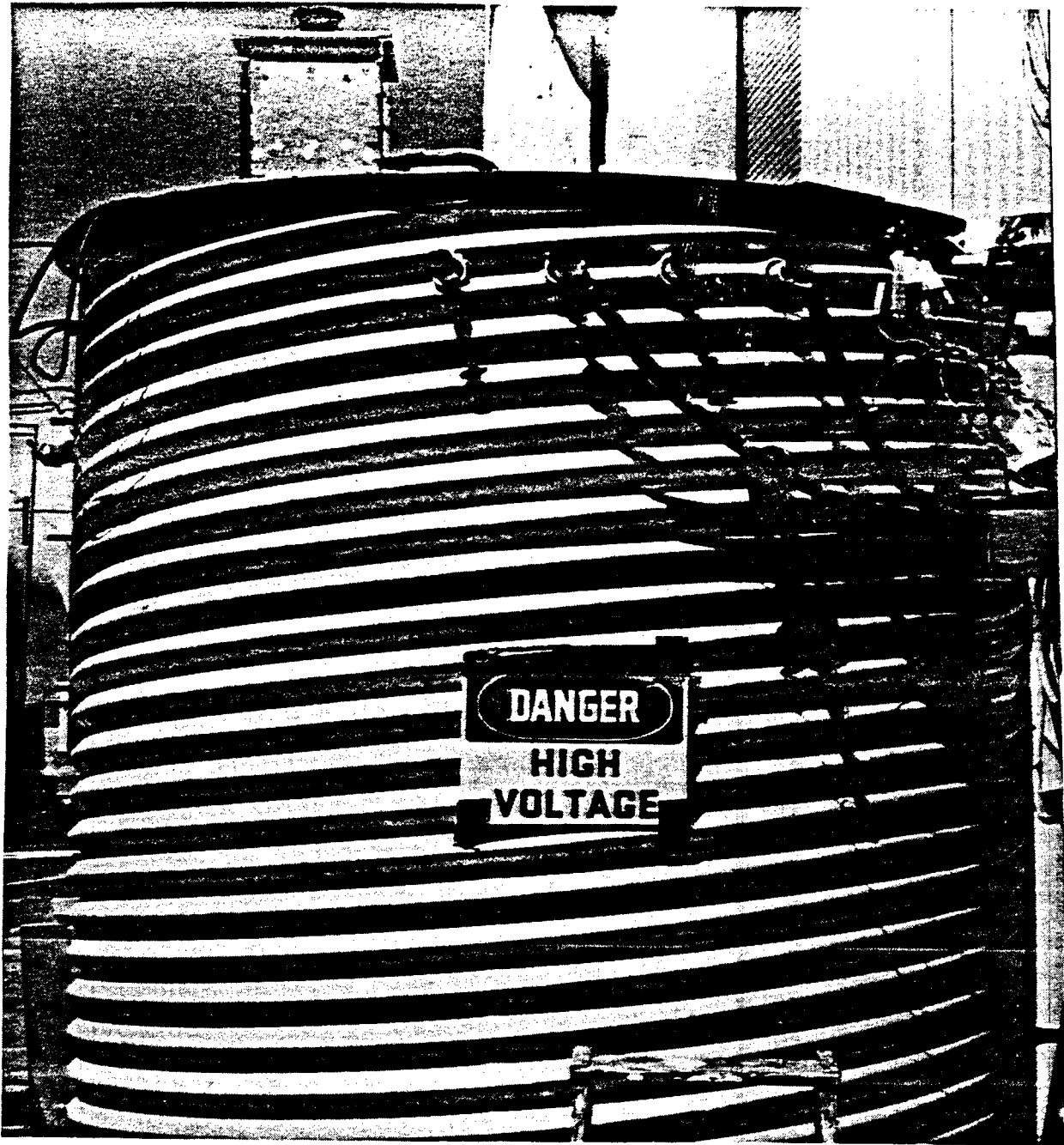


FIGURE 15. Engineering-Scale ISV Processing Container

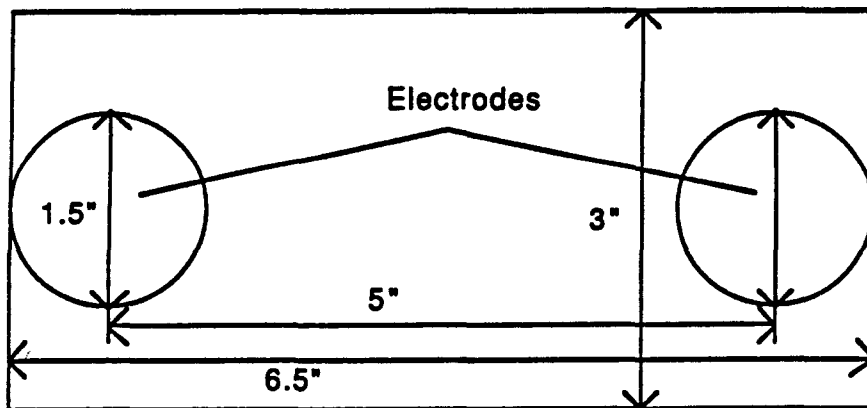
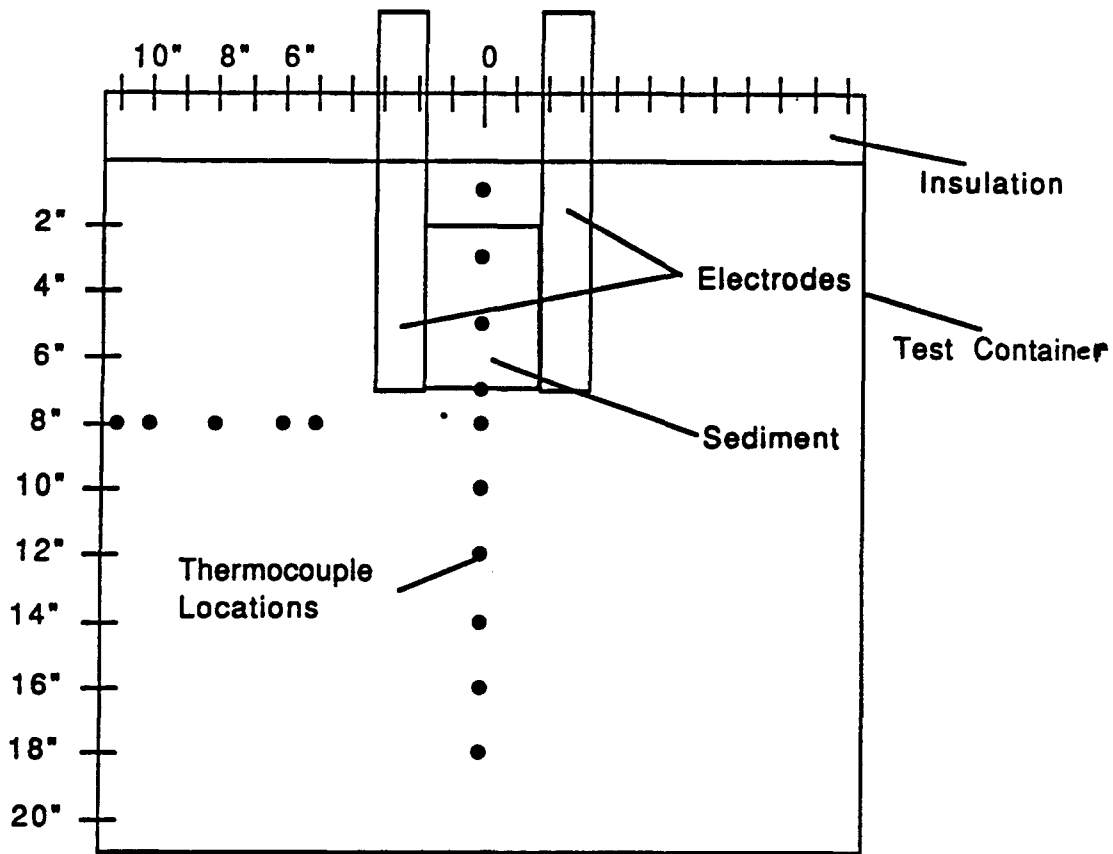


FIGURE 16. ISV Test Configuration: Sediment Placement and Thermocouple Locations (dimensions are in inches)

Figure 16 also shows the configuration of the sludge as positioned for this test. The sediment was placed between the electrodes from 5.1 cm (2 in.) below the soil surface to a depth of 17.8 cm (7 in.). The cross-sectional area containing the electrodes and sediment measured 7.6 cm (3 in.) by 16.5 cm (6.5 in.). The soil from the 17.8-cm (7-in.) to 50.8-cm (20-in.) depth was analyzed to monitor thermal migration effects to the surrounding soil. The contaminated material within the vitrification zone was totally consumed by the ISV melt.

Off gas from the vitrification zone was representatively sampled throughout the test with two sampling trains (Figures 17 and 18). The two sampling trains were designed to collect PCBs, dioxins, furans, and total chlorides.

The first sampling train (Train A, Figure 17) consisted of an EPA Reference Method 5 sampling scheme (40CFR60, Appendix A). Particulates were collected by drawing a representative sample from the 2-in. off-gas process line through a heated probe assembly leading into a glass fiber filter. The filter was housed in an oven compartment maintained at approximately 260°F. After exiting the filter/oven assembly, the gases were drawn through a series of three impingers containing a 0.1 N sodium hydroxide (NaOH) solution to scrub out chlorine radicals, such as HCl. A fourth empty impinger was placed in line to collect carry-over liquid/condensate, and the final impinger contained silica gel to trap water vapor. A control unit was used to monitor and control sampling rates, record sample volume, and track off-gas sampling temperatures during the vitrification.

A second sampling train (Train B, Figure 18) was incorporated into the off-gas line to collect PCBs, dioxins, and furans. This train consisted of a probe leading into a condenser connected to a small impinger. A series of two XAD-2 sorbent tubes were placed down-stream of the impinger to collect organics. Sampling flow rates were controlled by using a calibrated critical orifice coupled to a diaphragm pump. Appendix A contains more details concerning the off-gas sampling.

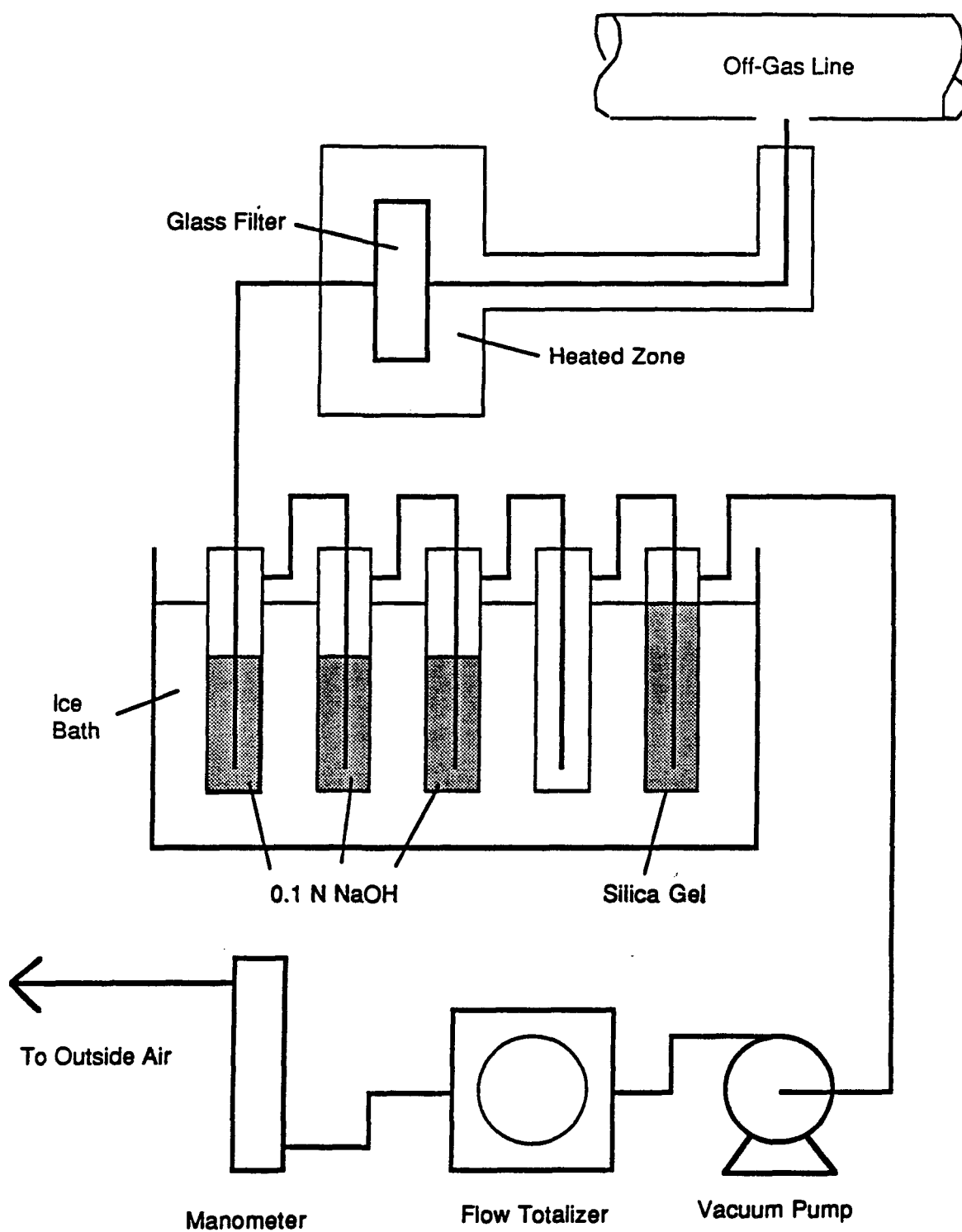


FIGURE 17. Particulate and Chloride Sampling Train (Train A)

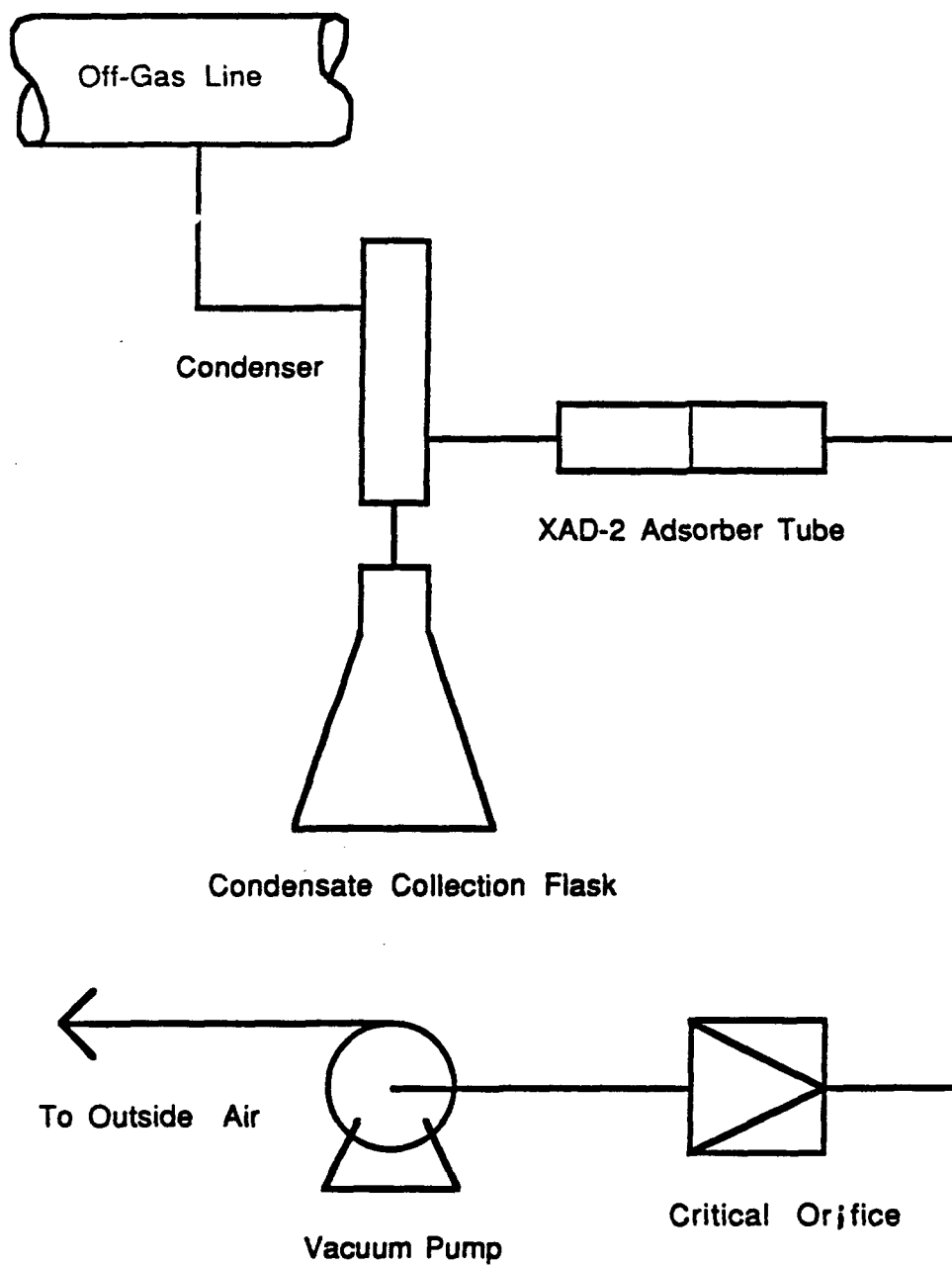


FIGURE 18. Organic Sampling Train (Train B)

TEST OPERATIONS

The bench-scale ISV test was conducted in September 1988 to assess the applicability of the ISV process for stabilizing PCB-contaminated sludges. Approximately 1.53 kg of PCB-contaminated sludge were vitrified. No operational problems were encountered during the test run. The high H₂O content of the sediment (69 wt%) did not appear to hinder the test operation. Vitrification processing proceeded to the 29.2-cm (11.5-in.) depth and produced an 8.2-kg (18 lb) block over a 3-hr period. This block was cylindrical and measured 15.7 cm (6.2 in.) in diameter across the middle and an average of 13.0 cm (5.12 in.) across the top of the block (Figure 19).

Average off-gas flow during the test was 29 scfm. From this flow, a representative sample was drawn at 0.5 cfm (13 L/min) through the particulate sample train (Train A), and 1 L/min through the organic sample train (Train B) to analyze for off-gas releases during processing.

Figure 20 illustrates the 100°C and 400°C isobank locations in the soil surrounding the vitrification zone, as determined from the thermocouple data. These bands are approximately 5.1 cm (2 in.) wide. The 400°C isoband is located approximately 1 in. from the vitrified block; the 100°C isoband, 12.7 cm (5 in.) from the block. These isobands represent regions where condensation and deposition of PCBs could occur during ISV processing. Condensation of PCB vapor occurs at 400°C (average PCB boiling point). Condensation/deposition of steam-stripped PCBs occurs at 100°C (condensation temperature of steam). The isobands were used to determine appropriate sampling locations of the surrounding soil. These samples were used to determine if PCB migration had occurred. The soil sample locations are also shown in Figure 20.

The high-temperature type C thermocouple data identified the actual operating melt temperature of 1860°C - 2100°C.

Electrical power data are given in Table 4. Electrical power and melt depth data for the ISV test are plotted in Figures 21 and 22, respectively. The total energy consumed for the test was 8.1 kWh. This provides an energy-to-mass ratio of 1.0 kWh/kg, which is within the normal range. Typical ratios measured for previous ISV tests have ranged from 0.8 to 1.1.

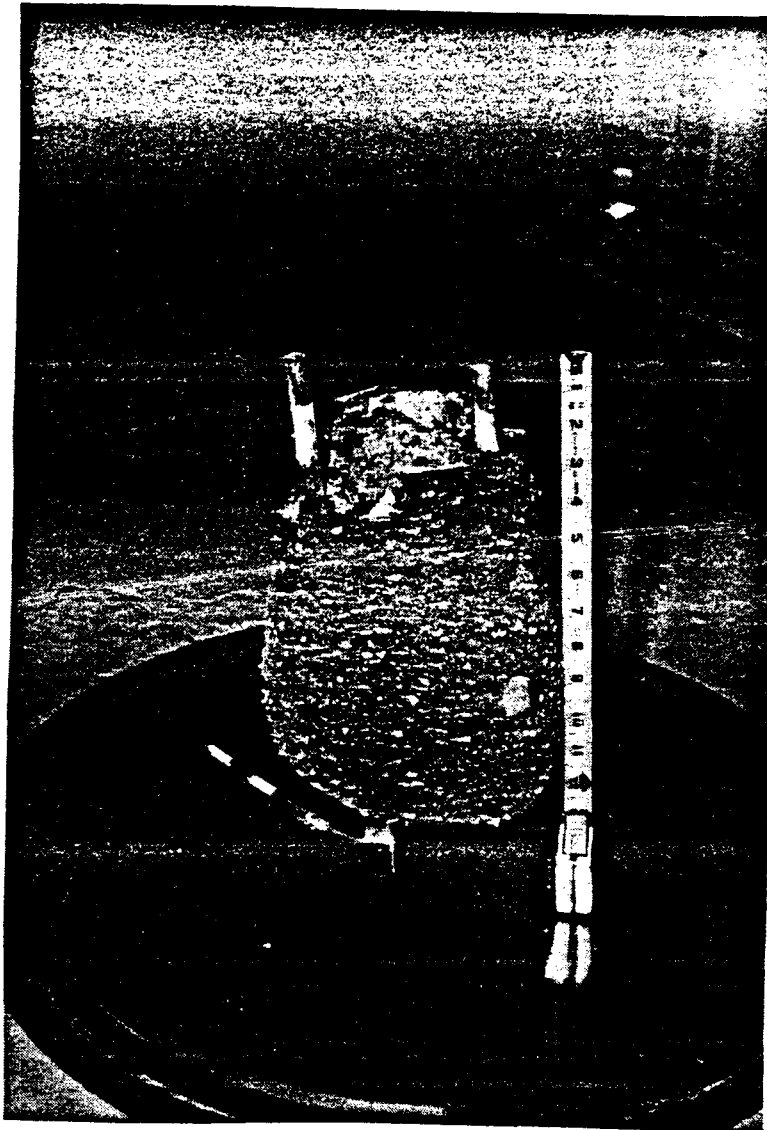


FIGURE 19. Vitrified Block Resulting from the ISV Process

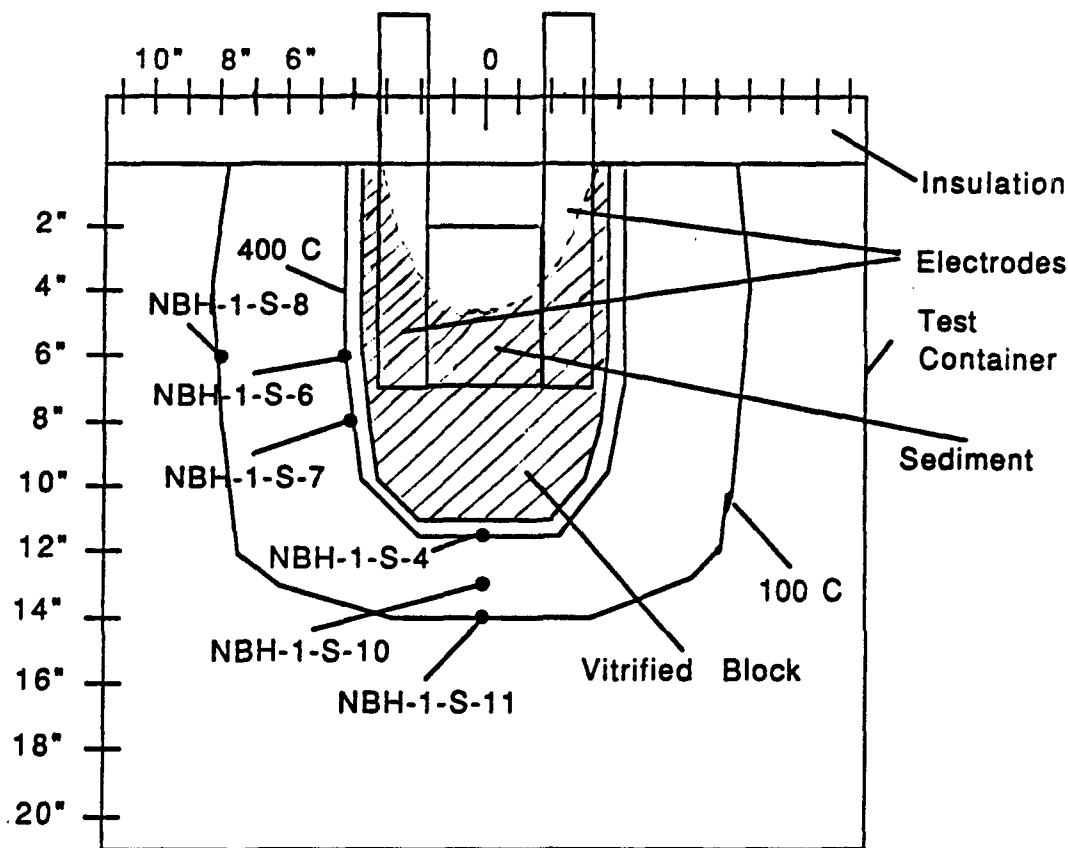


FIGURE 20. Soil Sample Locations and Isotherms: Soil Sample Locations as Labeled (Dimensions are in in.)

Power to the electrodes (Figure 21) was controlled to provide an accurate scale-down of the power density for the large-scale system. Power density is defined as $PD = P/A$ surface; where PD = power density (kW/m^2), P = power level (kW), and A = surface area of vitrification zone after startup material is consumed. The maximum power density of the large-scale system is $280 \text{ kW}/\text{m}^2$ ($26 \text{ kW}/\text{ft}^2$), which is based on a 3750-kW power supply and a minimum surface area between electrodes of 13.4 m^2 (144 ft^2). During the latter portion of the test, the power level averaged 4 kW and the surface area was 161.3 cm^2 (25 in.^2) [12.7-cm (5-in.) wide by 12.7-cm (5-in.) electrode separation] for a power density of $247.6 \text{ kW}/\text{m}^2$ ($23 \text{ kW}/\text{ft}^2$). This is within acceptable power density limits to confirm that these tests were operated under representative conditions.

TABLE 4. Power Performance Data

<u>Date</u>	<u>Run Time (h)</u>	<u>Amps</u>	<u>Volts</u>	<u>Watts</u>	<u>Watt-Hours</u>
12 Sep	0	10	56	560	0
12 Sep	0.07	18	52	936	52
12 Sep	0.40	38	36	1368	380
12 Sep	0.75	40	24	960	407
12 Sep	0.92	100	22	2200	269
12 Sep	1.22	43	103	4386	988
12 Sep	1.28	38	91	3458	235
12 Sep	1.47	41	102	4182	726
12 Sep	1.53	50	95	4750	268
12 Sep	1.78	32	80	2560	914
12 Sep	2.12	36	84	3024	949
12 Sep	2.32	45	82	3690	671
12 Sep	2.57	57	78	4446	1017
12 Sep	2.83	72	66	4752	1196
Total Power Consumed					8072

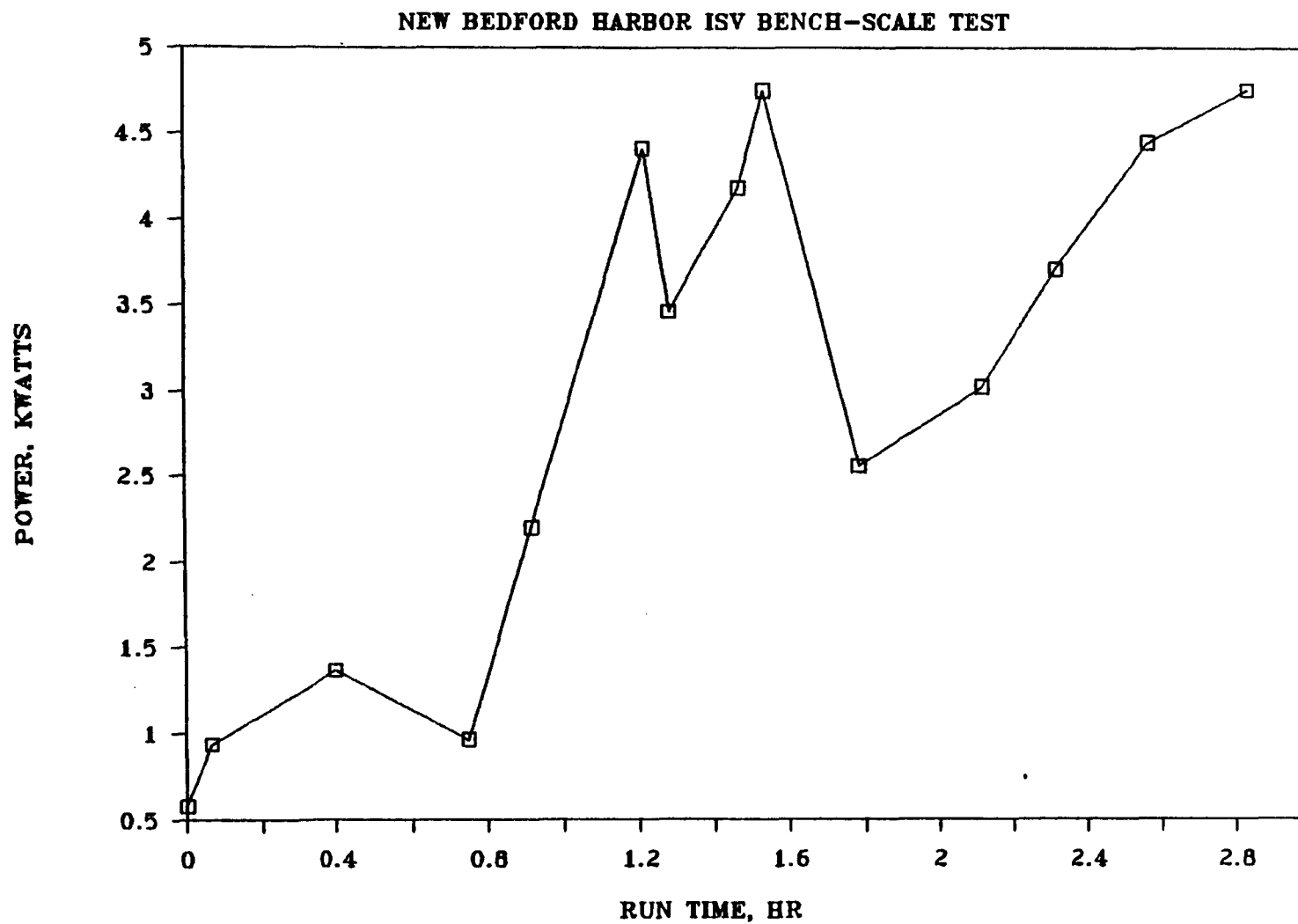


FIGURE 21. Electrical Power Performance

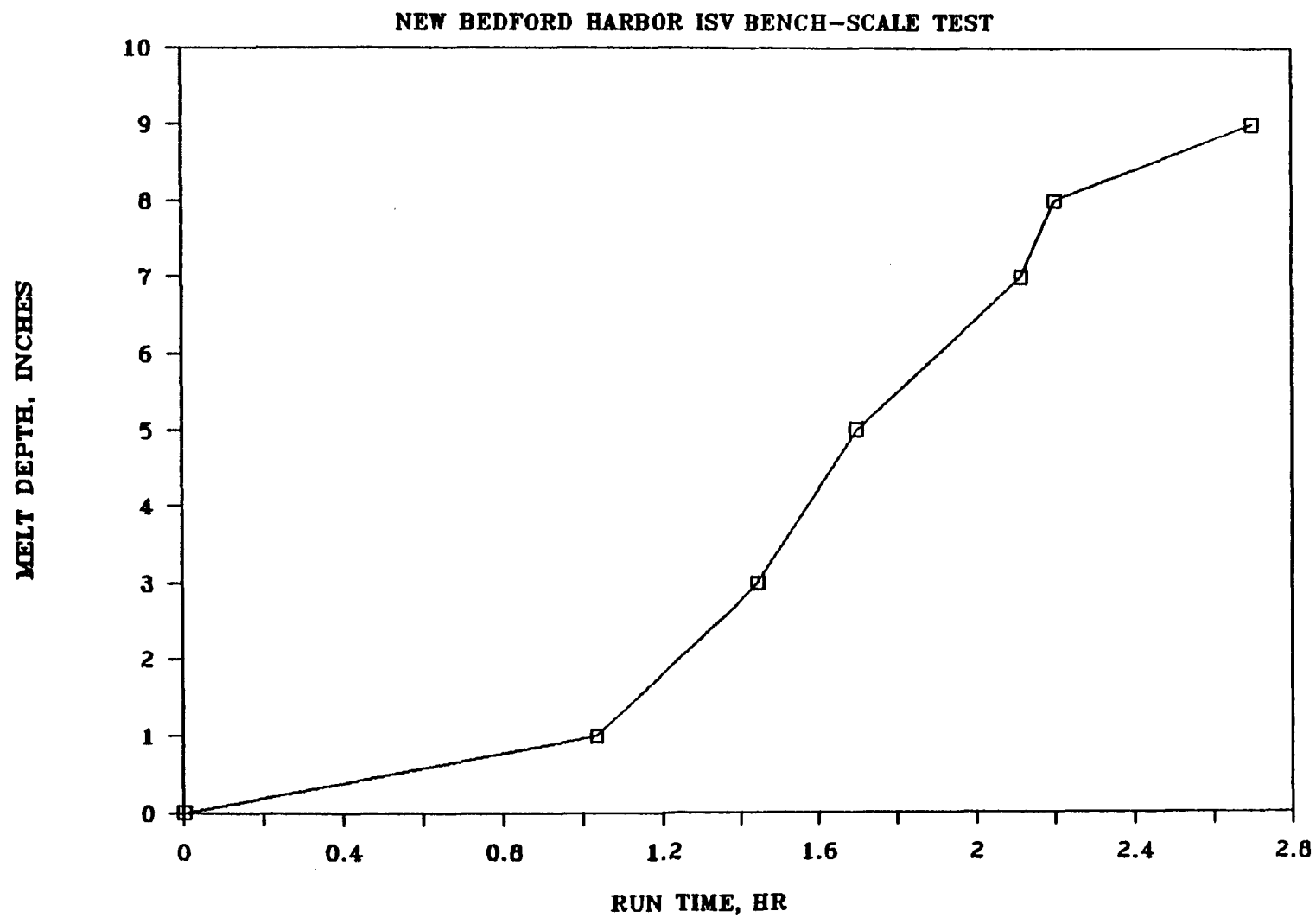


FIGURE 22. ISV Melt Depth Progression

TEST RESULTS

Following the test of the New Bedford Harbor sediment, analyses were conducted on the off-gas emissions to obtain PCB release information, the surrounding soil to determine PCB migration effects, and the vitrified block to determine specific material retention within the block. All analytical data indicate the feasibility of processing the PCB-contaminated sediment by ISV, in conjunction with the use of a wet scrubbing and sorption off-gas treatment system.

The bench-scale ISV test was performed over a 3-hour period and reached a depth of 22.9 cm (9 in.) according to thermocouple measurements. The block weighed 8.2 kg (18 lb). Post-test measurements indicated that the block was 29.2-cm (11.5-in.) deep with 12.7 cm (5 in.) of subsidence (see Figure 20). This 43% subsidence was caused by the densification of the soil and contaminants into the vitrified product during processing.

OFF-GAS CHARACTERIZATION

Off-gas stream sampling identified the amount of particulate released during processing. The off-gas system component analyses for PCBs, dioxins, furan, chloride (Cl^-), and metals are listed in Tables 5 and 6; scrub solution results and XAD-2 sorbent analyses in Table 5; and filter, lid smear, and insulation analyses in Table 6. Copies of the reports furnished by the analytical laboratory (Controls for Environmental Pollution, Inc.) are given in Appendix B.

All PCB, dioxin, and furan levels were reported to be below the detection limits of the analytical laboratory and are listed in Tables 5 and 6 as "less than" (<) quantities. These quantities vary for some of the components because of the sample volume or amount. The detection limits are based on $0.2 \mu\text{g/g}$ (ppm)^(a) or $0.2 \mu\text{g/L}$ (ppb)^(b) depending on whether the sample was a solid or liquid. The exactness of the reported quantities is questionable. The PCB concentrations of the blank or reference solutions/filter are

(a) $1 \mu\text{g/g} = 1 \text{ ppm}$, $1 \mu\text{g/kg} = 1 \text{ ppb}$.

(b) $1 \mu\text{g}/\mu\text{L} = 1 \text{ ppm}$, $1 \mu\text{g/L} = 1 \text{ ppb}$.

TABLE 5. Impinger Solution, Rinse, and XAD-2 Analyses

<u>Sample Description</u>	<u>PCBs, ppb</u>	<u>Dioxin, ppb</u>	<u>Furans ppb</u>	<u>Cl⁻, ppm</u>
Impinger solution-300 mL (0.1 N NaOH)	<2.0	NA	NA	9.00
Impinger solution-75 mL (0.1 N NaOH) Blank	<5.0	NA	NA	2.60
Train A-1st rinse (1:1 CH ₃ OH/CH ₂ Cl ₂) 75 mL	<2.0	NA	NA	NA
Train A-2nd rinse (1:1 CH ₃ OH/CH ₂ Cl ₂) 75 mL	<2.5	NA	NA	NA
Solvent Rinse Blank (1:1 CH ₃ OH/CH ₂ Cl ₂) 75 mL	<2.5	NA	NA	NA
XAD-2 Sorbent Tube	<0.2	<1.0	<1.0	NA

NA = not analyzed.

reported as quantities equal to or slightly greater than those of the samples collected during the test. The low levels of Cl⁻ detected do not raise concern for off-gas system corrosion. Further testing needs to be done to determine the level of Cl⁻ dissolved in the glass and the amount of Cl⁻ given off in the form of Cl₂ through the off-gas system.

Analyses of the filter particulate, lid smear, and insulation samples (Table 6) show that small amounts of cadmium and lead are volatilized during processing. The amounts of Cd and Pb volatilized are 1% and 2%, respectively, based on initial sediment concentrations of 37 ppb Cd and 1150 ppb Pb. The particulate commonly consists mostly of entrained particles such as fine dust and smoke. The analyses of the lid wipe and insulation give less than 0.80- and 0.04-ppm PCB concentrations, respectively. No significant plate-out of PCBs occurred in the test processing container.

TABLE 6. Particulate Analyses of Filter Insulation and Lid Smear(a)

<u>Material</u>	<u>Filter, μg</u>	<u>Filter Blank, μg</u>	<u>Lid Smear, $\mu\text{g/g}$ (ppm)</u>	<u>Insulation, $\mu\text{g/g}$ (ppm)</u>
PCBs	<0.40	<0.60	<0.80	<0.04
Ag	<2.00	<2.00		
As	<2.00	<2.00		
Ba	<20.00	<20.00		
Cd	12.80	<0.20		
Cr	<2.0	<2.0		
F	0.23	0.35		
Hg	<0.08	<0.08		
Pb	640.00	5.80		
Se	<2.00	<2.00		
Total wt. of particulate collected: 0.271 g				

(a) Lid smear and insulation analyzed for PCBs only.

GLASS AND SURROUNDING SOIL CHARACTERIZATION

Analyses of the vitrified (glass) product and samples of soil surrounding the vitrified block indicate that minimal migration of PCBs to the surrounding soil occurred. Table 7 gives the results of analysis for PCBs in one sample of glass and six samples of soil surrounding the vitrified block. This analytical work was provided by E.C. Jordan Co. Copies of the analytical reports are given in Appendix C. Detectable amounts of PCBs were not present in the glass or in half of the soil samples. The suspected presence of very small amounts of PCBs (<0.5 ppm), and only as Aroclor 1232, were identified in soil samples located in the general area of the 100°C soil isotherm (see Figure 20). The amounts of PCBs suspected (250 ppb, maximum) are well below the 40 CFR 761 clean-up level limit for nonrestricted access areas (10 ppm), and below other levels of concern commonly interpreted to be between 1 and 2 ppm. This indicates that PCB migration outside the vitrification zone was not a significant problem. For additional confirmation, testing of soil outside the 100°C isotherm should be performed. The PCB levels reported are within a factor of three of the reported detection limits, and thus some caution should be applied toward the data interpretation.

TABLE 7. Analyses of the Glass and Surrounding Soil

Pesticides/PCB	CRDL (a) $\mu\text{g/kg}$	Concentration ($\mu\text{g/kg}$)						
		NBH-1-G-2	NBH-1-S-4	NBH-1-S-11	NBH-1-S-6	NBH-1-S-8	NBH-1-S-7	NBH-1-S-10
Aroclor-1016	80	33 U ^(b)	33 U	34 U	33 U	34 U	33 U	33 U
Aroclor-1221	80	33 U	33 U	34 U	33 U	34 U	33 U	33 U
Aroclor-1232	80	33 U	33 U	120 X ^(c)	33 U	250 X	33 U	150 U
Aroclor-1242	80	33 U	33 U	34 U	33 U	34 U	33 U	33 U
Aroclor-1248	80	33 U	33 U	34 U	33 U	34 U	33 U	33 U
Aroclor-1254	160	67 U	67 U	67 U	67 U	67 U	67 U	67 U
Aroclor-1260	160	67 U	67 U	67 U	67 U	67 U	67 U	67 U
Percent Solid		100	100	100	100	100	100	100
Dilution Factor		1	1	1	1	1	1	1

(a) Contract-required detection limit.

(b) U = Below detection limit.

(c) X = Positive identification of Aroclor pattern could not be made. Presence is suspected.

The surrounding soil was not analyzed for the presence of dioxins and furans. A recently completed pilot-scale test with PCB-contaminated soil indicates that oxidation of PCBs to dioxins or furans does not occur in the vitrification zone or surrounding soil. Post-test analyses of the soil surrounding the vitrification zone revealed no detectable limits of either dioxons or furans. The oxidation is prevented by the reducing nature of the melt environment in the soil.

A sample of the vitrified product was subjected to leach testing using the EPA Toxicity Characteristic Leaching Procedure (TCLP). The TCLP test is applicable to ash product from RCRA^(a) Type B PCB incinerators. The test results for metal concentrations in the leach extract and maximum concentration limits established by the EPA in the leach extract are given in Table 8. As shown, the concentrations of regulated metals in the leach extract are below the regulatory limits. The extract was also analyzed for TCLP organics; those results are given in Appendix B.

THERMAL DESTRUCTION AND REMOVAL EFFICIENCY

Thermal destruction and removal efficiency (DRE) represents the fractional amount of contaminant destroyed and/or removed from the contaminated

TABLE 8. TCLP Extract Metal Concentrations: Vitrified Product

<u>Metal</u>	<u>Maximum Concentration (mg/L)</u>	<u>Vitrified Product (mg/L)</u>
As	5.0	<0.01
Ba	100.0	<0.1
Cd	1.0	<0.01
Cr	5.0	<0.01
Pb	5.0	<0.01
Hg	0.2	<0.0004
Se	1.0	<0.01
Ag	5.0	<0.01

(a) Resource Conservation and Recovery Act.

matrix. The DRE is defined for incinerators that burn hazardous waste in 40 CFR 264, and is determined from the following equation:^(a)

$$DRE = \frac{(W_{in} - W_{out})}{W_{in}} \times 100\% \quad (1)$$

where W_{in} = mass feed rate of the principal hazardous constituent in the waste stream feeding the incinerator (or mass of constituent in the waste to be treated).

W_{out} = mass emission rate of the principal hazardous constituent in exhaust emissions prior to release to the atmosphere (or mass of constituent released in the off-gas).

Table 9 lists the amounts of PCBs released to the off-gas system and existing on the process container and lid insulation as a result of plate-out. Since detectable amounts of PCBs were not found in the off-gas sampling system, lid smear, and insulation, the off-gas system release and plate-out were calculated based on the detection limits furnished by the analytical laboratory.

The % DRE for the ISV system is greater than 99.9985%. This value represents the amount of PCBs not released to the off-gas system and is based on PCB analytical detection limits. This % DRE, as calculated for this system, does not include the removal efficiency of the off-gas system itself.

TABLE 9. Amounts of PCBs Released from Vitrified Area through Off-Gas System

<u>Source</u>	<u>Amount Released, μg</u>
Organic Sampling Train (Train B analysis)	<198.83
Insulation Plate-Out	<104.01
Engineering-Scale Processing Container Plate-Out	<126.67

(a) 40 CFR 264.343(a)(1).

A single-stage activated carbon filter has a 99.9% organic removal efficiency (Charcoal Services Corporation). The ISV system soil-to-off-gas % DRE with a single-stage carbon filter is estimated to be greater than 99.99999 (seven nines). This is greater than the 99.9999% efficiency required by 40 CFR 761.70 for PCB incinerators. The carbon filters routinely used in the larger-scale ISV system are double-stage filters. With removal efficiencies of 99.9% per stage, the ISV system % DRE with a double-stage carbon filter is estimated to be greater than "9 nines."

SYSTEM MASS BALANCE - PCBs

An overall system mass balance for PCBs was performed. The amounts of PCBs released to the off-gas system, existing on the process container and lid insulation as a result of plate-out, present in the glass matrix, and present in the surrounding soil due to migration are listed in Table 10. The off-gas and plate-out components were presented in the DRE discussion above. Since detectable amounts of PCBs were not found in the glass matrix (vitrified block), the amount of PCBs present was calculated based on the detection limits furnished by the analytical laboratory. The maximum amounts of PCBs present in the soil surrounding the vitrified material were calculated using the largest concentration of PCBs suspected in the soil (250 ppb).

TABLE 10. Total Amounts of PCBs Released from Vitrified Area

<u>Source</u>	<u>Amount Released, μg</u>
Organic Sampling Train (Train B analysis)	<198.83
Insulation Plate-Out	<104.01
Engineering-Scale Processing Container Plate-Out	<126.67
Glass Matrix	1,312
Soil Surrounding Vitrified Product: to 100°C Isoband (see Figure 20)	16,320

The overall mass balance for the ISV system shows that greater than 99.94% of the PCBs were destroyed by the process. The % PCBs destroyed was calculated by subtracting the amount released to the off-gas system, plate-out within the system (none detected; detection limit used for calculation), amount in glass matrix (none detected; detection limit used for calculation), and the limited amount of migration to the surrounding soil (based on suspected presence limited by analytical detection techniques). The amount of PCBs released to the soil was assumed to be the amount contained in the volume of surrounding soil up to the 100°C isothermal band. This amount was calculated as a conservative case, with the maximum suspected concentration of PCBs detected (250 ppb) used to calculate the amount of PCBs present in this soil volume. A greater understanding of PCB behavior should be more thoroughly pursued in larger-scale tests.

ECONOMIC ANALYSIS AND LARGE-SCALE APPLICATION

Bench-scale testing of ISV's capability to treat wastes produces conservative results compared to actual large-scale ISV performance on the wastes. Prior tests have indicated that ISV performance in all areas improves with increasing scale. Relative to the effectiveness of the process to destroy/remove PCBs, the effectiveness improves with increased scale because of the greatly increased melt depth and dwell time (i.e., exposure time of hazardous materials to the melt temperature). Process economics also improve directly with scale in that thermal losses are minimized and indirect labor input (e.g., time spent moving the hood and placing electrodes) is minimized compared to direct labor input (time spent monitoring vitrification operations).

Projected costs for ISV at New Bedford Harbor must be supplied on a site-specific basis. In 1988, Battelle transferred the rights of ISV for nonfederal government, chemical hazardous wastes to Geosafe Corporation in Kirkland, Washington. Consequently, site-specific costs for ISV application to New Bedford sediments must be supplied by Geosafe.

APPENDIX D

Previous estimates for vitrifying contaminated soil have been provided for generic, federal applications (Buel et al. 1987). The cost information provided in that reference should be considered preliminary and not directly applicable to the site-specific cost projections for the New Bedford sediments. However, the reference does provide a basis for estimating costs for applying ISV at federal contaminated soil sites. These costs include estimates of capital amortization as well as labor, electrical energy, and materials to support ISV operations.

The conditions of the New Bedford sediments have been input to an ISV mathematical model described by Buel et al. (1987). The model accounts for soil moisture and soil and glass densities associated with New Bedford sediments to predict the melt shape and energy requirements for vitrifying the sediments to a 5-m depth. The model predicts energy requirements of 1.04 kWh/kg, which is corroborated by the bench-scale test result of 1.0 kWh/kg. The maximum and average block widths are 7.8 and 6.8 m, respectively, meaning the center point of each setting should be placed 6.8 m

apart with 0.5-m overlap with each adjacent setting. Each setting of four electrodes spaced 4.5 m apart vitrifies 250 m^3 of sediment in 106 h. Consequently, allowing for 16 h between settings for equipment moves and allowing for a 70% total operating efficiency, the model predicts that $10,000 \text{ m}^3$ ($13,000 \text{ yd}^3$) of contaminated sediments could be vitrified in 40 settings over a 9-month period with a single unit. Alternatives to this configuration such as vitrifying repetitive batches of sediments in a single setting can be provided by Geosafe.

Utilization of ISV at the New Bedford Site will require that the sediments be dredged and located onshore for processing. The sediments may be processed by ISV either at, above, or below grade. In order to achieve good production economics, it will be necessary to place the sediments at a depth in the range of 4.6 to 15.2 m. Since depths of 5 m have been demonstrated with existing equipment, it would be advisable to maintain sediment depths at the lower end of this range. It may be desirable to place a shallow (i.e., 30 to 60 cm) layer of clean soil over the sediment prior to processing to minimize release of vaporized PCBs during startup.

There may be economic incentive to allow some gravity dewatering and air drying prior to processing. The technology is capable of processing fully saturated sediments; however, there is an economic penalty associated with the energy required to vaporize and remove the water. The effect of possible mechanical dewatering on total costs should be explored before committing to a final operational plan.

The large-scale ISV system (of present design) is capable of processing 4 to 6 tons/h to treat a single setting volume of 382 to 765 m^3 , depending on configuration. Increased production rates can be achieved for large-volume applications by using more than one large-scale machine or by using specially designed equipment with greater throughput capability. There is no physical or technological condition limiting scale to the present large-scale configuration. Rather, this equipment was sized so that it would fit on trailers suitable to classify it as mobile equipment. It is possible to design larger-scale equipment if specific site conditions warrant. Individual setting size and processing rate capabilities could also be increased; this would result in further economies of scale.

Large-scale ISV processing equipment enjoys some inherent reliability features that most other technologies do not. Since the process involves electric melting, there is a minimum of moving equipment parts associated with applying energy to the contaminated soil. The only moving equipment associated with the energy application system is the transformer cooling fans. This feature is considered a very significant advantage compared to other thermal processes employing burners or other moving equipment items in high-temperature zones, or in contact with high-temperature waste materials.

The off-gas treatment system uses conventional unit process equipment that will be required by any thermal treatment process, assuming that they will all have to collect and treat off-gases. This equipment will be designed to be readily serviceable and replaceable. The off-gas treatment system is technologically simple so that adequate margins of safety and reliability are easily obtained.

It is not expected that utilization of ISV will require any great difficulty in the construction area. It is noted that the residual glass monoliths produced should be suitable for delisting as hazardous materials and could be left in place, where processed. If for some reason it was necessary to remove the monoliths, they would have to be broken into transportable sizes; this would require additional costs. It is conceivable that the monolith segments could be returned to the harbor without imposing any risk of heavy metal leaching at rates above acceptable limits. The residual material should qualify for land disposal at any location after delisting. It is obvious that the lowest cost option would be to leave it in place where produced. The residual product is expected to have excellent strength properties, and thus should be capable of supporting construction above it (i.e., parking lot, buildings).

It is also noted that the residual product will be of much lower volume than the starting sediment volume. Because of the high water content, it is expected that a volume reduction of 40% to 60% may be achieved. The volume reduction will result in subsidence in the processing area. If the processing is done at grade level, it may be desirable to backfill with clean soil to restore grade and to allow vegetation to grow. The depth of the

residual product surface can be controlled by controlling the starting elevation of the sediment for processing.

Equipment availability is not considered to limit the technology. The equipment consists of an assembly of major subsystems that are procured from vendors specializing in certain areas (e.g., electrical transformers, glycol radiators, scrubbers). It is possible to assemble large numbers of systems simultaneously; the rate is dependent only upon the availability of subsystem components. It is not expected that any subsystem component will have a delivery lead time in excess of 6 months.

Treatment and handling of secondary scrubber and filter wastes is not expected to pose a problem for ISV processing. Ideally, as part of the treatment process, any contaminated scrubber solution and filter materials should be placed into the next available setting. In this way essentially all of the PCBs and heavy metals at the site will be either destroyed (PCBs) or immobilized (heavy metals). Only a very small amount of secondary waste resulting from the last ISV setting at the site would require final disposal. That amount would be insignificant compared to the large quantities of hazardous wastes processed. That final secondary waste could be readily disposed in some other ISV setting or sent to conventional treatment facilities.

Battelle believes the bench-scale testing corroborates that ISV technology is applicable for use on the New Bedford harbor sediments. For additional information and details, refer to Buel et al. (1987). This document is very comprehensive and addresses many areas of concern regarding ISV process implementation.

REFERENCES

- Buel, J. L., and J. G. Carter. 1986. In Situ Vittrification Large-Scale Operational Acceptance Test Analysis. PNL-5828, Pacific Northwest Laboratory, Richland, Washington.
- Buel, J. L., and J. G. Carter. 1986b. Description and Capabilities of the Large-Scale In Situ Vittrification Process. PNL-5738, Pacific Northwest Laboratory, Richland, Washington.
- Buel, J. L., and S. T. Freim. 1986. Demonstration of In Situ Vittrification for Volume Reduction of Zirconia/Lime Sludges. Prepared for Teledyne Wah Chang, Albany, Oregon, under Contract 2311205327. Pacific Northwest Laboratories, Richland, Washington.
- Buel, J. L., C. L. Timmerman, K. H. Oma, V. F. FitzPatrick, and J. G. Carter. 1987. In Situ Vittrification of Transuranic Waste: An Updated Systems Evaluation and Applications Assessment. PNL-4800 Suppl. 1, Pacific Northwest Laboratory, Richland, Washington.
- Charcoal Services Corporation, "High Efficiency Gas Adsorbers," Charcoal Services Corporation, Bath, North Carolina. Bulletin No. 283A.
- Lazar, I. 1977. "Making the choice Among Dry, Liquid, and Gas Transformers." Specifying Engineer 37:130-131.
- Oma, K. H., D. R. Brown, J. L. Buel, V. F. FitzPatrick, K. A. Hawley, G. B. Mellinger, B. A. Napier, D. J. Silveira, S. L. Stein, and C. L. Timmerman. 1983. In Situ Vittrification of Transuranic Wastes: Systems Evaluations and Applications Assessment. PNL-4800, Pacific Northwest Laboratory, Richland, Washington.
- Timmerman, C. L. 1986. In Situ Vittrification of PCB-Contaminated Soils. EPRI CS-4839, Electric Power Research Institute, Palo Alto, California.
- Timmerman, C. L., R. A. Brouns, J. L. Buel, and K. H. Oma. 1983. "In Situ Vittrification: Pilot-Scale Development." Nuclear and Chemical Waste Management, 4:267.
- Timmerman, C. L. and K. H. Oma. 1984. An In Situ Vittrification Pilot-Scale Radioactive Test. PNL-5240, Pacific Northwest Laboratory, Richland, Washington.

APPENDIX A
OFF-GAS SAMPLING

TARGET SHEET

THE MATERIAL DESCRIBED BELOW
WAS NOT SCANNED BECAUSE:

- ☐ OVERSIZE
- ☐ NON-PAPER MEDIA
- ☒ OTHER

Site: New Bedford Harbor

Description: Appendix A: Off-Gas Sampling

Doc ID: 288685

THE OMITTED MATERIAL CONTAINS CONFIDENTIAL BUSINESS
INFORMATION (CBI) AND IS AWAITING DETERMINATION. IF YOU HAVE
ANY QUESTIONS, PLEASE CALL THE OSRR RECORDS AND INFORMATION
CENTER AT (617) 918 - 1440

APPENDIX B

ANALYTICAL RESULTS FROM CONTROL FOR ENVIRONMENTAL POLLUTION, INC.

PAGE 1
RECEIVED: 10/10/88

CEP, Inc.

REPORT

10/28/88 16:17:14

OUT OF STATE 800/545-2188

LAB # 88-10-173

REPORT Battelle
TO Pacific Northwest Labs.
P.O. Box 999
Richland, Washington 99352
ATTN Craig Timmerman

CLIENT BATTELLE SAMPLES 6
COMPANY Battelle
FACILITY Pacific Northwest Labs.

WORK ID Water Quality
TAKEN _____
TRANS Federal Express
TYPE Liquid
P.O. # U5678 Contract B-U5678-C-U
INV. # 430391

PREPARED Controls for Environmental
BY Pollution, Inc.
1925 Rosina Street
Santa Fe, NM 87502
ATTN _____
PHONE (505) 982-9841


CERTIFIED BY

CONTACT GAIL

Remainder of sample(s) for routine analysis will be disposed
of three weeks from final report date. Sample(s) for bacteria
analysis only, will be disposed of one day after final report.
This is not applicable if other arrangements have been made.

Note: Detection limits varies because sample volume of amount
varies. Detection limits based on 0.2 ug/g or 0.2 ug/l.

Duplicate of report of 10/27/88.

SAMPLE IDENTIFICATION

01 BST-NBH-1-MM5-3 Imp. Sol.
02 BST-NBH-1-MM5-4
03 BST-NBH-1-MM5-5
04 BST-NBH-1-MM5-6
05 BST-NBH-1-MM5-7
06 BST-NBH-1-L-1 Lid Wipe

CEP, Inc.

TEST CODES and NAMES used on this report

AQ 1 Silver
AS 1 Arsenic
BA 1 Barium
CD 1 Cadmium
CL 1 Chloride
CR 1 Chromium
F 1 Fluoride
HQ 1 Mercury
NO3 1 Nitrate, Nitrogen (as N)
PB 1 Lead
PCB 1 Polychlorinated Biphenyls
SE 1 Selenium



PAGE 2

REPORT OF ANALYSIS

LAB #

88-10-173

SAMPLE IDENTIFICATIONDATE COLLECTEDTYPE OF ANALYSISmq/liter

BST-NBH-1-MM5-3 Imp. Sol.

not specified

Silver

<0.01

Arsenic

<0.01

Barium

<0.1

Cadmium

<0.001

Chloride

9.0

Chromium

<0.01

Fluoride

<0.05

Mercury

0.0006

Nitrogen, Nitrate (as N)

0.1

Lead

<0.01

Polychlorinated Biphenyls

<2.0

(ug/liter)

Selenium

<0.01

BST-NBH-1-MM5-4

not specified

Silver

<0.01

Arsenic

<0.01

Barium

<0.1

Cadmium

<0.001

Chloride

2.6

Chromium

<0.01

Fluoride

<0.05

Mercury

<0.0004

Nitrogen, Nitrate (as N)

<0.1

Lead

<0.01

Polychlorinated Biphenyls

<5.0

(ug/liter)

Selenium

<0.01

BST-NBH-1-MM5-5

not specified

Polychlorinated Biphenyls

<2.0

(ug/liter)

BST-NBH-1-MM5-6

not specified

Polychlorinated Biphenyls

<2.5

(ug/liter)

BST-NBH-1-MM5-7

not specified

Polychlorinated Biphenyls

<2.5

(ug/liter)

BST-NBH-1-L-1 Lid Wipe

not specified

Polychlorinated Biphenyls

<0.8

(ug/gram)




PAGE 1
 RECEIVED: 10/10/88

CEP, Inc. REPORT
 10/28/88 16:32:40

LAB # 88-10-172

REPORT Battelle
 TO Pacific Northwest Labs.
P.O. Box 999
Richland, Washington 99352
 ATTN Jerome Skinner

PREPARED Controls for Environmental
 BY Pollution, Inc.
1925 Rosina Street
Santa Fe, NM 87502
 ATTN _____
 PHONE (505) 982-9841


 CERTIFIED BY _____
 CONTACT GAIL

CLIENT BATTELLE SAMPLES 2
 COMPANY Battelle
 FACILITY Pacific Northwest Labs.

Remainder of sample(s) for routine analysis will be disposed
of three weeks from final report date. Sample(s) for bacteria
analysis only, will be disposed of one day after final report.
This is not applicable if other arrangements have been made.

WORK ID Water Quality
 TAKEN _____
 TRANS Federal Express
 TYPE Particulate Filter
 P.O. # U5678 Contract B-U5678-C-U
 INVOICE under separate cover

SAMPLE IDENTIFICATION

CEP, Inc. TEST CODES and NAMES used on this report

01 BST-NBH-1-MM5-1
 02 BST-NBH-1-MM5-2

A0 A Silver
 AS A Arsenic
 BA A Barium
 CD A Cadmium
 CR A Chromium
 F A Fluoride
 H0 A Mercury
 NO3 A Nitrate, Nitrogen (as N)
 PB A Lead
 PCB 5 Polychlorinated Biphenyls
 SE A Selenium



Controls for Environmental Pollution, Inc.

10000 Wilshire Blvd., Suite 100, Santa Fe, New Mexico 87502

505/982-9841

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PAGE 1

CEP, Inc.

REPORT

LAB # 88-10-174

RECEIVED: 10/10/88


10/28/88 16:17:41

REPORT Battelle
TO Pacific Northwest Labs.
P.O. Box 999
Richland, Washington 99352
ATTEN Craig Timmerman

CLIENT BATTELLE SAMPLES 2
COMPANY Battelle
FACILITY Pacific Northwest Labs.

WORK ID Water Quality
TAKEN _____
TRANS Federal Express
TYPE Solid
P.O. # U5678 Contract B-U5678-C-U
INV. # 430392

PREPARED Controls for Environmental
BY Pollution, Inc.
1925 Rosina Street
Santa Fe, NM 87502
ATTEN _____
PHONE (505) 982-9841


CERTIFIED BY _____
CONTACT GAIL

Remainder of sample(s) for routine analysis will be disposed
of three weeks from final report date. Sample(s) for bacteria
analysis only, will be disposed of one day after final report.
This is not applicable if other arrangements have been made.

Duplicate of report of 10/27/88.

SAMPLE IDENTIFICATION
01 BST-NBH-1-MM5-9 S. Tube
02 BST-NBH-1-IN-1 Lid Insul.

CEP, Inc. TEST CODES and NAMES used on this report
DIOX 5 Dioxin
FURANS Furan
PCB 5 Polychlorinated Biphenyls



Controls for Environmental Pollution, Inc.

P.O. Box 5431 • Santa Fe, New Mexico 87502

Phone: 505/832-1411

OUT OF STATE 800/F45-2188

PAGE 2

REPORT OF ANALYSIS

LAB #

88-10-174

SAMPLE IDENTIFICATION

BST-NBH-1-MM5-9 S. Tube

DATE COLLECTED

not specified

TYPE OF ANALYSIS

Dioxin

Furan

PCB's

ug/sample

<1.0

<1.0

<0.2

BST-NBH-1-IN-1 Lid Insul.

not specified

PCB's

<0.04

(ug/gram)



Controls for Environmental Pollution, Inc.
19301 351 Santa Fe, New Mexico 87502

STATE 505 982-9841
OUT OF STATE 800/545-2188

PAGE 1
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CEP, Inc. REPORT
11/04/88 15:24:46

LAB # 88-10-324

REPORT Battelle
TO Pacific Northwest Labs.
P.O. Box 999
Richland, Washington 99352
ATTEN Jerome Skinner
CLIENT BATTELLE SAMPLES 1
COMPANY Battelle
FACILITY Pacific Northwest Labs.
WORK ID Water Quality
TAKEN _____
TRANS Airborne
TYPE Glass
P.O. # _____
INVOICE under separate cover

PREPARED Controls for Environmental
BY Pollution, Inc.
1925 Rosina Street
Santa Fe, NM 87502
ATTEN _____
PHONE (505) 982-9841


CERTIFIED BY

CONTACT GAIL

Remainder of sample(s) for routine analysis will be disposed
of three weeks from final report date. Sample(s) for bacteria
analysis only, will be disposed of one day after final report.
This is not applicable if other arrangements have been made.

SAMPLE IDENTIFICATION
01 BST-NBH-1-0-3 Post-Test

CEP, Inc. TEST CODES and NAMES used on this report

<u>AQ 1</u>	<u>Silver</u>
<u>AS 1</u>	<u>Arsenic</u>
<u>BA 1</u>	<u>Barium</u>
<u>CD 1</u>	<u>Cadmium</u>
<u>CR 1</u>	<u>Chromium</u>
<u>HQ 1</u>	<u>Mercury</u>
<u>PB 1</u>	<u>Lead</u>
<u>SE 1</u>	<u>Selenium</u>
<u>TCLP 0</u>	<u>TCLP Organics</u>
<u>ZHE</u>	<u>Zero Head Space Extraction</u>



Controls for Environmental Pollution, Inc.

12011 - 3510 San Antonio, New Mexico 87502

6-1088 505-1982 JH11

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PAGE 2

REPORT OF ANALYSIS

LAB #

88-10-324

SAMPLE IDENTIFICATION

BST-NBH-1-G-3 Post-Test

DATE COLLECTED

not specified

TYPE OF ANALYSIS

mq/liter

Silver	<0.01	(mg/liter TCLP)
Arsenic	<0.01	(mg/liter TCLP)
Barium	<0.1	(mg/liter TCLP)
Cadmium	<0.01	(mg/liter TCLP)
Chromium	<0.01	(mg/liter TCLP)
Mercury	<0.0004	(mg/liter TCLP)
Lead	<0.01	(mg/liter TCLP)
Selenium	<0.01	(mg/liter TCLP)
TCLP Organics		()
Zero Head Space Extraction		()



PAGE 3

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CEP, Inc.

REPORT

LAB # 88-10-324

Results by Sample

SAMPLE ID BSI-NBH-1-G-3 Post-TestFRACTION 01BTEST CODE TCLP 0NAME TCLP OrganicsDate & Time Collected not specifiedCategory SOLID

CAS #	Compound name	Regulatory Limit (mg/L)	Result
111-44-4	Bis(2-chloroethyl)ether	0.05	<5.7
95-48-7	o-Cresol	10.0	<10.0
108-39-4	m-Cresol	10.0	<10.0
106-44-5	p-Cresol	10.0	<10.0
87-86-5	Pentachlorophenol	3.6	<3.6
108-95-2	Phenol	14.4	<14.4
58-90-2	2,3,4,6-Tetrachlorophenol	1.5	<10.0
95-95-4	2,4,5-Trichlorophenol	5.8	<10.0
88-06-2	2,4,6-Trichlorophenol	0.30	<2.7
121-14-2	2,4-Dinitrotoluene	0.13	<5.7
118-74-1	Hexachlorobenzene	0.13	<1.9
87-66-3	Hexachlorobutadiene	0.72	<0.9
67-72-1	Hexachloroethane	4.3	<1.6
98-95-3	Nitrobenzene	0.13	<1.9
57-74-9	Chlordane	0.03	<0.28
72-20-8	Endrin	0.003	<0.12
76-44-8	Heptachlor	0.001	<0.06
58-89-9	Lindane	0.06	<0.08
72-43-5	Methoxychlor	1.4	<2.0
8001-35-2	Toxaphene	0.07	<1.0
94-75-7	2,4-D	1.4	<1.0
93-76-5	Silvex	0.14	<0.1
95-50-1	1,2-Dichlorobenzene	4.3	<1.9
106-46-7	1,4-Dichlorobenzene	10.8	<4.4

NOTES AND DEFINITIONS FOR THIS REPORT

All results reported in mg/liter unless otherwise specified.



Controls for Environmental Pollution, Inc.

151 Kings Highway East, New Milford, CT 07502

PHONE 505.982.9411

OUT OF STATE 800/545-2188

PAGE 4

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CEP, Inc.

REPORT

LAB # 88-10-324

Results by Sample

SAMPLE ID BST-NBH-1-G-3 Post-Test

FRACTION Q1B

TEST CODE ZHE

NAME Zero Head Space Extraction

Date & Time Collected not specified

Category SOLID

CAS #	Compound name	Regulatory Limit (mg/L)	Result
107-13-1	Acrylonitrile	5.0	<10.0
71-43-2	Benzene	0.07	<4.4
751-50-4	Carbon disulfide	14.4	<5.0
56-23-5	Carbon tetrachloride	0.07	<2.8
108-90-7	Chlorobenzene	1.4	<6.0
67-66-3	Chloroform	0.07	<1.6
107-06-2	1,2-Dichloroethane	0.40	<2.8
75-35-4	1,1-Dichloroethylene	0.10	<2.8
78-83-1	Isobutanol	36.0	<10.0
75-09-2	Methylenechloride	8.6	<2.8
78-93-3	Methylethyl ketone	7.2	<6.0
110-86-1	Pyridine	5.0	<15.0
630-20-6	1,1,1,2-Tetrachloroethane	10.0	<6.0
79-34-5	1,1,2,2-Tetrachloroethane	1.3	<6.9
127-18-4	Tetrachloroethylene	0.10	<4.1
108-88-3	Toluene	14.4	<6.0
71-55-6	1,1,1-Trichloroethane	30.0	<3.8
79-00-5	1,1,2-Trichloroethane	1.2	<5.0
79-01-6	Trichloroethylene	0.07	<1.9
75-01-4	Vinyl chloride	0.05	<10.0

NOTES AND DEFINITIONS FOR THIS REPORT

All results reported in ug/liter unless otherwise specified.

APPENDIX C

SOIL AND GLASS ANALYTICAL RESULTS PROVIDED BY E. C. JORDAN CO.

TRANSMITTAL MEMORANDUM

4959-21

DATE: October 31, 1988
TO: Mary Ann Reimus, Battelle-NW, FAX 509-376-1867
FROM: Douglas C. Allen, E.C. Jordan
SUBJECT: USEPA-CLP Results for Battelle-NW Vitrification
Bench-Test Program

Attached with this memo are the results of the USEPA contract laboratory program (CLP) analyses for PCBs in vitrified New Bedford Harbor sediment.

I was informed by my CLP tracking people that the lab responsible for the metals analysis has been having equipment problems. Therefore, the results of these analyses will be delayed. We are currently attempting to get a commitment from that lab for completion of the analyses.

If you have any questions regarding these results, please do not hesitate to contact me.

APPENDIX TABLE		PROJECT: New Bedford Harbor						
SAMPLE LOCATION: NBH-1-G-2		NBH-1-S-4	NBH-1-S-11	NBH-1-S-6	NBH-1-S-8	NBH-1-S-7	NBH-1-S-10	
SNO NUMBER: 4163A-07		4163A-06	4163A-05	4163A-04	4163A-03	4163-02	4163A-01	
MATRIX: SOIL		SOIL	SOIL	SOIL	SOIL	SOIL	SOIL	
PESTICIDES/PCB		CRDL ug/kg						
Aroclor-1016	80	33 U	33 U	34 U	33 U	34 U	33 U	
Aroclor-1221	80	33 U	33 U	34 U	33 U	34 U	33 U	
Aroclor-1232	80	33 U	33 U	120 X	33 U	250 X	33 U	
Aroclor-1242	80	33 U	33 U	34 U	33 U	34 U	33 U	
Aroclor-1248	80	33 U	33 U	34 U	33 U	34 U	33 U	
Aroclor-1254	160	67 U	67 U	67 U	67 U	67 U	67 U	
Aroclor-1260	160	67 U	67 U	67 U	67 U	67 U	67 U	
Percent Solid		100	100	100	100	100	100	
Dilution Factor		1	1	1	1	1	1	

X = Positive identification of Arochlor pattern could not be made. Presence is suspected.

SUMMARY TABLE

PROJECT: New Bedford Harbor

SAMPLE LOCATION: NBH-1-G-2		NBH-1-S-4	NBH-1-S-11	NBH-1-S-6	NBH-1-S-8	NBH-1-S-7	NBH-1-S-10	
SMO NUMBER: 4163A-07		4163A-06	4163A-05	4163A-04	4163A-03	4163-02	4163A-01	
MATRIX: SOIL		SOIL	SOIL	SOIL	SOIL	SOIL	SOIL	
PESTICIDES/PCB	CRDL ug/kg							
Aroclor-1232	80	-	-	120 X	-	250 X	-	150 X
Percent Solid		100	100	100	100	100	100	100
Dilution Factor		1	1	1	1	1	1	1

X = Positive identification of Aroclor pattern could not be made. Presence is suspected.

TRANSMITTAL MEMORANDUM

4959-21

DATE: November 14, 1988
TO: Mary Ann Reimus, Battelle-NW, FAX 509-376-1867
FROM: Douglas Allen, E.C. Jordan
SUBJECT: USEPA-CLP Results for Battelle-NW Vitrification
Bench-Test Program

Attached with this memo are the results of the USEPA contract laboratory program (CLP) analyses for metals in vitrified New Bedford Harbor sediment.

If you have any questions regarding these results, please contact Steve Turner at E.C. Jordan (207-774-5401 x726).

Appendix Table

SAMPLE ID:			1-S-10	1-S-7	1-S-8	1-S-6	1-S-11	1-S-4	1-S-1
LAB NUMBER:			MAK 433	MAK 434	MAK 435	MAK 436	MAK 437	MAK 438	MAK 439
DATE SAMPLED:			9/16/88	9/16/88	9/16/88	9/16/88	9/16/88	9/16/88	9/16/88
MATRIX:			SOIL	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL
METALS COMPOUNDS	ANALYTICAL								
UNITS: mg/kg	METHOD	CRDL							
Aluminum	P	40	2240	2310	2770	2570	2420	2610	246
Antimony	P	12	29 N	34 N	38 N	31 N	30 N	43 N	5.1 UN
Arsenic	F	2	2.4	2.4	2.5	2.6	2.5	2.5	0.84 U
Barium	P	40	49	42	53	37 []	48	52	10 U
Beryllium	P	1	1.9	1.3	1.7	1.2	1.8	1.7	0.42 U
Cadmium	P	1	1.8	1.2	1 U	1.9	2.2	1.1	1.1 U
Calcium	P	1000	4690 E	5150 E	5310 E	4960 E	5150 E	5440 E	2050 E
Chromium	P	2	1.2 U	1.2 U	1.3 []	2 []	1.2 U	1.2 U	1.3 U
Cobalt	P	10	6.5 []	6.9 []	7.3 []	6.2 []	6.8 []	7.2 []	2.1 U
Copper	P	5	36 N	4.6 []N	27 N	23 N	9.7 N	16 N	37 N
Iron	P	20	14300 E	13500 E	14600 E	12900 E	13800 E	15200 E	1850 E
Lead	P/F	1	2.5	2.5	3.1	4.1	2.4	0.57 []	-
Magnesium	P	1000	2820	2760	3200	2910	2840	3070	730 []
Manganese	P	3	207 E	189 E	229 E	194 E	198 E	212 E	26 E
Mercury	CV	0.04	0.46	0.1 U	0.1 U	0.11 U	0.1 U	0.1 U	0.11 U
Nickel	P	8	4.6 []	5 []	5.8 []	4.6 []	5 []	7.5 []	1.7 U
Potassium	P	1000	462 []	584 []	633 []	189 U	188 U	190 []	189 U
Selenium	F	1	0.41 U	0.41 U	0.41 U	0.42 U	0.42 U	0.41 U	0.42 U
Silver	P	2	12 N	10 N	12 N	11 N	12 N	12 N	1.1 UN
Sodium	P	1000	967 []	1030	1000 []	1130	979 []	1020 []	953 []
Thallium	F	2	1 U	1 U	1 U	1.1 U	1 U	1.02 U	1.1 U
Vanadium	P	10	25	19	23	24	23	25	2 []
Zinc	P	4	31	27	32	28	29	37	5.9
Percent Solids			97	97	97	95	96	98	95

C.5

Validation Table

SAMPLE ID:	1-S-10	1-S-7	1-S-8	1-S-6	1-S-11	1-S-4	1-G-1
LAB NUMBER:	MAK 433	MAK 434	MAK 435	MAK 436	MAK 437	MAK 438	MAK 439
DATE SAMPLED:	9/16/88	9/16/88	9/16/88	9/16/88	9/16/88	9/16/88	9/16/88
MATRIX:	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL

METALS COMPOUNDS	ANALYTICAL	
UNITS: mg/kg	METHOD	CRDL

Aluminum	P	40	2240	2310	2770	2570	2420	2610	246
Antimony	P	12	29 J	34 J	38 J	31 J	30 J	43 J	5.1 UJ
Arsenic	F	2	2.4	2.4	2.5	2.6	2.5	2.5	0.84 U
Barium	P	40	49	42	53	37 []	48	52	10 U
Beryllium	P	1	1.9	1.3	1.7	1.2	1.8	1.7	0.42 U
Cadmium	P	1	1.8	1.2	1 U	1.9	2.2	1.1	1.1 U
Calcium	P	1000	4690 J	5150 J	5310 J	4960 J	5150 J	5440 J	2050 J
Chromium	P	2	1.2 U	1.2 U	1.3 []	2 []	1.2 U	1.2 U	1.3 U
Cobalt	P	10	6.5 []	6.9 []	7.3 []	6.2 []	6.8 []	7.2 []	2.1 U
Copper	P	5	36 J	4.6 [] J	27 J	23 J	9.7 J	16 J	37 J
Iron	P	20	14300 J	13500 J	14600 J	12900 J	13800 J	15200 J	1850 J
Lead	P/F	1	2.5	2.5	3.1	4.1	2.4	0.57 []	0.58 []
Magnesium	P	1000	2820	2760	3200	2910	2840	3070	730 []
Manganese	P	3	207 J	189 J	229 J	194 J	198 J	212 J	26 J
Mercury	CV	0.04	0.46	0.1 U	0.1 U	0.11 U	0.1 U	0.1 U	0.11 U
Nickel	P	8	4.6 []	5 []	5.8 []	4.6 []	5 []	7.5 []	1.7 U
Potassium	P	1000	462 []	584 []	633 []	189 U	188 U	190 []	189 U
Selenium	F	1	0.41 U	0.41 U	0.41 U	0.42 U	0.42 U	0.41 U	0.42 U
Silver	P	2	12 J	10 J	12 J	11 J	12 J	12 J	1.1 UR
Sodium	P	1000	967 []	1030	1000 []	1130	979 []	1020 []	953 []
Thallium	F	2	1 U	1 U	1 U	1.1 U	1 U	1.02 U	1.1 U
Vanadium	P	10	25 J	19 J	23 J	24 J	23 J	25 J	2 [] J
Zinc	P	4	31	27	32	28	29	37	5.9
Percent Solids			97	97	97	95	96	98	95

C.6

Summary Table

SAMPLE ID:	1-S-10	1-S-7	1-S-8	1-S-6	1-S-11	1-S-4	1-G-1
LAB NUMBER:	MAK 433	MAK 434	MAK 435	MAK 436	MAK 437	MAK 438	MAK 439
DATE SAMPLED:	9/16/88	9/16/88	9/16/88	9/16/88	9/16/88	9/16/88	9/16/88
MATRIX:	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL	SOIL

METALS COMPOUNDS	ANALYTICAL	CRDL
UNITS: ng/kg	METHOD	

Aluminum	P	40	2240	2310	2770	2570	2420	2610	246
Antimony	P	12	29 J	34 J	38 J	31 J	30 J	43 J	-
Arsenic	F	2	2.4	2.4	2.5	2.6	2.5	2.5	-
Barium	P	40	49	42	53	-	48	52	-
Beryllium	P	1	1.9	1.3	1.7	1.2	1.8	1.7	-
Cadmium	P	1	1.8	1.2	-	1.9	2.2	1.1	-
Calcium	P	1000	4690 J	5150 J	5310 J	4960 J	5150 J	5440 J	2050 J
Copper	P	5	36 J	-	27 J	23 J	9.7 J	16 J	37 J
Iron	P	20	14300 J	13500 J	14600 J	12900 J	13800 J	15200 J	1850 J
Lead	P/F	1	2.5	2.5	3.1	4.1	2.4	-	-
Magnesium	P	1000	2820	2760	3200	2910	2840	3070	-
Manganese	P	3	207 J	189 J	229 J	194 J	198 J	212 J	26 J
Mercury	CV	0.04	0.46	-	-	-	-	-	-
Silver	P	2	12 J	10 J	12 J	11 J	12 J	12 J	R
Sodium	P	1000	-	1030	-	1130	-	-	-
Vanadium	P	10	25 J	19 J	23 J	24 J	23 J	25 J	-
Zinc	P	4	31	27	32	28	29	37	5.9
Percent Solids			97	97	97	95	96	98	95

C.7

APPENDIX D

PRELIMINARY ISV COST ESTIMATE PREPARED BY GEOSAFE CORPORATION

GEOSAFE CORPORATION
PRELIMINARY ISV COST ESTIMATE

1. DEFINITION:

Date: January 31, 1989

Site Name: New Bedford Harbor Superfund Site

Site Location: New Bedford, Massachusetts

2. ASSUMPTIONS:

Contaminants/Concentrations: PCBs - $\leq 20,000$ ppm (total)
Other organics - ≤ 200 ppm
Heavy metals - ≤ 100 ppm

Heat Value of Contaminants: Insignificant

Required Cleanup Levels: PCBs - 99.9999% DRE

Soil Type/Composition: Sediment (no chemical
composition provided)

Energy/Mass Ratio: Approximately 1.0 kwh/kg

Soil Moisture Content: Sediment provided with partial
dewatering complete. [50% (volume)
water and 50% solids; 38% (weight)
water and 62% solids]. Further
dewatering does not occur in staged
trench.

Soil Permeability: Not pertinent; to be staged above
water table

Depth to Groundwater: Not pertinent; to be staged above
water table

Recharge Rate: Not pertinent; to be staged above
water table

Volume to be Treated: Case 1 - 10,000 yd³ as dewatered
Case 2 - 50,000 yd³ as dewatered
Case 3 - 500,000 yd³ as dewatered

<u>Dry Density:</u>	1.6 gm/cc
<u>Depth of Processing:</u>	15-ft (as staged)
<u>Tonnage to be Treated:</u>	Case 1: 6,500 tons solids containing 4,200 tons water
	Case 2: 32,500 tons solids containing 21,000 tons water
	Case 3: 325,000 tons solids containing 210,000 tons water
<u>Presence of Inclusions:</u>	None
<u>Price of Electricity:</u>	\$0.08/kwh maximum
<u>Cost of Electrical Service:</u>	Insignificant; service available
<u>Run Time/Setting:</u>	Approximately 110 hrs/setting
<u>Number Settings Required:</u>	Case 1 - 31 Case 2 - 155 Case 3 - 1,550
<u>Total Processing Time:</u>	Case 1 - 190 days (1 machine) Case 2 - 820 days (1 machine) Case 3 - 1,800 days (4 machine)
<u>Volume Treated/Setting:</u>	Approximately 320 yd ³ /setting
<u>Tonnage Treated/Setting:</u>	Approximately 435 tons/setting
<u>Expected Melt Dimensions:</u>	27-ft x 27-ft x 15-ft deep

=====

3. TIME AND COST ESTIMATES BY CATEGORY:

Treatability Testing: (including sample characterization, ISV melt testing, complete analytical and documentation)

- Previously completed -

Pre-Operational Technical Support: (including support of site characterization, site preparation, application engineering, and permitting/ARARs compliance activities)

Support provided on hourly rate basis (typical \$65/hr) for specific technical support requested. Note that Geosafe is in process of applying for national TSCA permit for PCBs and has much documentation applicable to ARARs compliance needs.

Mobilization/Demobilization: (including transport of equipment, onsite erection, readiness testing, post-project decontamination, disassembly, and transport to base location)

Cases 1 and 2: \$211,000 (possibility of \$70-80,000 credit if equipment is next mobilized to another EPA site without >30-day delay). Mobilization time is <1-week; demobilization time is < 10 days.

Case 3: \$844,000 (4-machines required to meet project's 5-yr completion deadline); same mobilization and demobilization times estimates as for cases 1 and 2. Possible demobilization credit of \$70-80,000 per machine that is mobilized to another EPA site within 30-days.

Vitrification Operations: (including all direct costs of operations ... burdened labor, materials, electric power, off-gas treatment, movement between settings, equipment amortization and maintenance)

Case 1: \$330/ton

Case 2: \$310/ton

Case 3: \$290/ton

Post-Operational Technical Support: (including support of site restoration, post-project sampling/monitoring, and delisting activities)

Support provided on hourly rate basis (typical \$65/hr) for specific technical support requested.

4. COSTS NOT INCLUDED:

Site characterization, site preparation, permitting/regulatory compliance, excavation and staging of materials for processing (if any), site restoration, delisting, secondary waste disposal, any other non-ISV related costs.

5. COST SENSITIVITY:

Moisture Content: Each 10% (by weight) reduction in moisture may reduce cost by \$12-16/ton

Price of Electricity: Each \$0.02/kwh reduction in price of power may reduce cost by \$27-32/ton
(note: such reduction is considered possible to obtain)

Depth of Processing: Each 5-ft additional staging depth may reduce cost by \$16-19/ton

Other: Possible credit of approximately \$5,000/setting if electrode casing placement work can be included in staging contract.
